EMERGING PERSPECTIVES
IN
SCIENCE EDUCATION RESEARCH

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Contents

Editor's Introduction (i)

About the Authors (xi)

PART - I SCIENCE EDUCATION RESEARCH : AN ANALYSIS

1. Science Education Research : Purposes and Priorities 1
T. N. WANCHOO
J. K. SOOD

2. Science Education Research in India : An Analysis 16
J. K. SOOD

3. Research in Mathematics Education : An Analysis 23
G. N. BHARDWAJ

PART - II SCIENCE CURRICULUM EVALUATION

4. Formative and Summative Evaluation of Science Curricula 44
J. K. SOOD

5. Evaluation of Science Curricula 60
PRITAM SINGH

PART – III PIAGETIAN THINKING AND SCIENCE EDUCATION

6. Research on Piagetian Thinking in Science 76

H. P. SINGH

7. The Problematic Territory of Jean Piaget and Adolescent Thought 91

N. VAIDYA

8. Implications of Piagetian Research for Science Curriculum Development 102

A. C. PACHAURY

9. Research on Piagetian Thinking Some Efforts at Punjab University 137

J. N. JOSHI

PART – IV SOCIOLOGY OF SCIENCE EDUCATION

10. Sociology of Science Education Problems and Research Perspectives 140

S. P. RUHELA

11. Directions For the Future : Science Education Research in India [illegible]

J. K. SOOD

Editor's Introduction

The Department of Education in Science and Mathematics of the National Council of Educational Research and Training has initiated many activities for the improvement of school science teaching. Its one of the major endeavours has been to improve the quality of research in science education, with its direct bearing on the classroom instruction

It is well known that some of the Universities and Regional Colleges of Education have started Science Education Programmes at the Ph D and M Ed levels However, the point of concern arises from the two intriguing, initial observations So far Science Education has not been accepted as a scholarly discipline, and there are only a few dedicated scholars working in the field of Science Education These observations were substantially proved by the synthesizers of Science Education Research in India. With these shortcomings in mind, the first attempt was made to survey the researches done at the Ph.D. and M.Ed. levels in the different universities and institutions in India This effort was analyzed and consolidated at a workshop organized at Trivendrum All science educators from the Southern States in India pooled their opinion and consolidated the material Second workshop on Research in Science and Mathematics Education was organized at Amritsar with an entirely different group of science educators The materials developed at Trivendrum were crystalized in this workshop, and research gaps were identified An analysis of more than 600 reseach studies and identification of research gaps is in itself a pioneer effort It has been published in the first research monograph entitled

In the first paper Prof. Wanchoo and Dr. [illegible] have discussed the purpose of science education research in the context of emerging perspectives in science and [illegible]. Science education research should be instrumental in solving the problems. The selection of research problems should be on the priority basis to meet the national demands.

In the second paper, Dr. Sood has presented a review of science education research done in India at the Ph.D. and M.Ed. levels. The research gaps and needed precautionary measures to under take research have also been discussed.

Dr. Bhardwaj has presented a review of Mathematics Education Research conducted in the U.S.A. and India. The author has made a case for Mathematics Education Research necessitated by the varied changes coming up in the spheres of Mathematics teaching. The paper also includes different areas of research in Mathematics Education and gives suggestions for future research.

Science curriculum development programmes have been the most significant activites during the Post Sputnik era. Recently science curriculum evaluation has been taken as an undetachable part of science curriculum research. The investment in terms of man power and money has been stupendous and many workers have started raising the question of accountability. Other group was active in determining the gains, which students have from new science curriculum materials. These gains were spelled out in terms of intellectual, academic and attitudinal advantages. Since then formative and summative evaluative processes have gained currency.

Mr. Preetam Singh in his paper "Evaluation of

Science Curriculum" has laid emphasis on the advantages of curriculum evaluation. It is recorded that there is a need of determining the proper, adequate use of the resources, development of the attitudes, values among the students and the effectiveness of the teaching strategies. In this context, the author has recommended the need to rationalize the curriculum development procedures. It is also suggested that curriculum should be relevant to the objectives of science education content methodology of science and teaching effectiveness. The author has developed a theoretical framework or rationale for planning the curriculum evaluation model and a detailed outline has been mentioned.

The paper on "Formative and Summative Evaluation of Science Curriculum" by Dr. Sood has highlighted the concept of formative and summative evaluation alongwith the researches attempted in this area. Some examples of the formative summative evaluation used by the different Science Curriculum Projects have been included. The need of such researches in Indian classroom has been emphasized by the author.

Jean Piaget is an empirical genetic epistemologist and his name shines in many educational journals throughout the world. It is truism to say that Piagetian Thinking has become a part of educational endeavour in most of the systems. Since 1950 it has become increasingly clear to child psychologists, educators and others in diverse areas that "Jean Piaget is the foremost contributor to the field of intellectual development in recent decades. This has a pertinent relation to curriculum planning and imparting of instructions. Many Science Curriculum Projects in the U. S. A. and U. K. have taken into account the observations made in Geneva

School There is a question for our immediate consideration" How can Piagets thought's be integrated in Science Curriculum and science instruction in Indian situation ? This monograph includes three papers on Piagetian Thinking to seek an answer of such questions.

Dr. R P Singh in his Paper "Research on Piagetian Thinking in Science" presents an exhaustive discussion on specific stages of intellectual growth among children, as propounded by Piaget The author has mentioned many research studies in support of intellectual maturation and their relationship to science teaching While discussing the educational implications of Piagetian thinking, the author has developed relationship between individual child's intellectual development and educational problems He has further given valuable suggestions for planning science curriculum congruent with the developmental stages of the learner as mentioned by Piaget

The author has expressed a strong feeling that there is a direct link between developmental stage and grade placement of concepts The author has given some references relevant to science education with a pious hope that some studies will also be conducted in our classrooms

Mr Pachauri has given an exhaustive list of researches attempted on Piagetian Thinking in his paper "Implications of Piagetian Research for Science Curriculum Development" On the basis of the analysis of research, the author has forcefully advised for a Piagetian theory-based curriculum and its evaluation This is of much significance in the conditions where students do not attain formal thinking even after attending advanced course at the school stage. Researches have proved it in connection with "Alphabet" courses in the U. S. A.

Piagetian system has a direct bearing on conceptually based research in science education. This type of research has not been attempted by adequate number of researchers.

Prof. M. Vaidya has discussed the problems related to Piagetian Thinking and research implication. The author has quoted the pioneer study undertaken by him. This study not only reestablishes the work done by Joan piaget but suggests further implications.

Since world war II many pertinent questions were raised about the role and methods of science in schools. Similar questions were again raised after the launching of the Sputnick and a need for basic changes in scientific education was realized. Science is a system of knowledge and like any knowledge it has its own sociology. Scholars like Bernard Barber, Walter Hirsch, Talcott Parsons, and Robert K. Merton etc have put forth strong points in favour of Sociology of science. A vigorous effort was made by these sociologists to break the isolation of society. Recently there is a great awareness among the intellectuals to understand the relationship between science and society. Merely discussing merits and demerits of science in school curricula is insufficient if there is no critical understanding of the problems and possibilities of the relationship of science and society. By now sociology of science has emerged as a fully grown field of study. There is an urgent need to present detached and critical view of science which may enable the researcher or student to view the emer press of science from [illegible] and to place it and himself in its social context. Science is a social phenomenon and its social dimensions are to be discussed [illegible] of central social and cultural importance and [illegible] an [illegible] on other major social institutions

The paper on "Sociology of Science Education: Problems and Research Perspectives" by Dr. Ruhela goes beyond sociology of science and includes both the Sociology of Science as well as the sociology of science education. It is a well documented paper within Indian perspective and extrapolates the research needs in this virgin area. The author has unearthed a new area in science education which is of recent origin. He has discussed the following four sub-areas in his paper

1. The essentials of Sociology of Science
2. The core ideas in the Sociology of classroom teaching
3. The implications of sociological foundation of education for science teaching in schools
4. Research needs in science education in India

The author has discussed the premises of sociology of science with specific emphasis on the relationship of science and society. The opinions expressed by eminent authorities in the field from time to time have been included. He also includes many sociological ideas with a bearing on science in schools and research in science education. The paper focuses the discouraging picture of science teaching in schools and makes a strong plea for its improvement

The author contends that some research topics in the sociological perspectives should be attempted, and the factors such as, rural urban social groupings, religion, economy, traditions etc., in relation to science teaching should be taken up by research workers. In addition to it, research should also be related to teacher education and its different aspects.

Dr. Joshi has provided a list of research studies on Piagetian thinking which were attempted at the Punjab University, Chandigarh. The titles of these studies will prove helpful to understand the nature of the work which is being attempted in this country. Towards the end an attempt has been made to put out some ideas about the directions for the future as well as the theoretical aspects of science education research. It will be helpful in understanding the different needs of science education research and in determining a future line of action.

Since Independence varied and valuable programmes have been launched to upgrade science teaching in our schools. New science text books were prepared, new instructional material was generated and new research areas were uncovered. The time has come now to launch research-oriented science teaching. Hopefully, this monograph will prove a small yet significant addition to the professional literature.

All papers of this monograph are aimed not only at research analysis in different areas but also to bridge the communication gap among the fellow researchers. The consolidation of research and time cover will be a helping hand to a novice in the profession in coordinating different attempts and in attempted through the evidences to choose the relevant, recent problem.

The editor is deeply indebted to all the
papers have been included in this monograph.
Warm thanks go to Dr. G. N. Bhardwaj need special
thanks for his guidance and help in organizing the

selecting the themes, and in the preparation of the material.

Dr. H. M. Behl and Mr. T. S. [illegible] have helped a lot in bringing out this book. The editor is grateful to them. The editor is extremely obliged to the editors of the Indian Educational Review and the Teacher Education for permitting us to publish the papers of Dr. Behl and [illegible] which were prepared for this book.

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PART I Science Education Research : An Analysis

1

Science Education Research : Purposes and Priorities

V. N. Wanchoo
J. K. Sood

The significance of science has been realized by all and a due place has been given to it in formal education. Some efforts are also being made to popularise science through non-formal education. For the last thirty years there has been significant progress in the areas of science curriculum, science text books, preparation of instructional materials and development of relevant evaluative procedures. These changes were witnessed not only in India but in other countries also. Massive efforts concerning science curriculum programmes were made in 1960s. U S A is a case in point. In due course of time it assumed an international movement. In India these new approaches were initiated through Science Summer Institutes. Since 1963 many efforts have been made to acquaint the science teachers with the philosophy and rationale of the new science curriculum so that they can make use of it in teaching and developing science materials

These efforts have been proved very useful. It appears that the foundation is ready to support further growth and answer to many pertinent questions raised from time to time. Unfortunately, the case is not as simple as it appears apparently because sufficient research support to establish quality teaching in science was never provided at the classroom level. It is increasingly being felt that rethinking in science education is needed. Though the questions of accountability and humanization are most important yet some other questions need immediate attention of the profession. These questions are :---

The turning of students away from science courses,

A feeling of disjunction between science and society,

The value free science curriculum, and Nurturing the potential creative talent from different social strata.

Scope of Science Education :

The above mentioned questions need immediate answers so as to provide relevance to science education. Conventional approach to science education does not pay rich dividends. Science teaching should not be taken as the statement of the facts or a process of imparting scientific information as it develops a misconception among the students. Students feel that science emerges from the science teacher or science text books. Many schools and Colleges of Education are presenting science as fact-oriented-discipline, there by, delimiting the scope of science education. Sometimes the shortage of science equipments, inadequately trained science teachers, and unimaginative teaching mars the spirit of science and depict science as dehumanized and impersonal activity. The scope is narrowed down to an unbelievable extent. But radical reform is in the offing. Recent efforts have indicated that to make science education meaningful, it is essential that science curriculum should be matched within the wide cultural and societal context. The American Association for the Advancement of Science has very aptly mentioned:

"........ it concerns itself with the quality of man and the quality of human life and devotes itself not only to discovery and dissemination of scientific truths but more so to the humanistic values" (AAAS, Council Meeting, 1971).

Similarly the UNESCO Commission on Education in their report, entitled, *Learning to Be* (1972) has laid emphasis on the new approach to science education in the following words:

"The never ending evolution in science makes traditional methods of teaching less and less acceptable. We cannot hope to absorb the knowledge explosion by cramming brains with more scientific facts and by removing out-dated subjects from the curriculum. On the contrary, science teaching should be based on a pragmatic search for solutions to problems arising out of the environment either directly from reality or derived from models."

Very recently, Rais Ahmad (1976) has visualized the rightful role of science in national development. He says,

"...... ...... The bridges between theory and practice, and between science and technology on the one hand and aspirations of the people on the other hand, should be bridged to make education relevant to social needs. Science education should fulfil the objectives of education which have been identified as being essential .... Science education must share the responsibilities of education in the fullest sense of

world. It must be based on science as part of human culture, so that citizens are able to comprehend their environment and to interact with it in a meaningful way while making a critical appraisal of all the implications. Science education must help develop the creative faculties of the students... .
In the first place the intimate relationship between science, social science, and the humanities which we observe in our environment and in our society, should be reflected in the curriculum, particularly at primary level . . ....It is also essential to use the environment as a basis of research and inquiry."

Therefore, a continuous effort is needed to present science in its proper prespective adequately based upon research findings. Research findings will add new dimensions to current practices, and ultimately research support will help in building quality in teaching and learning of science.

Teaching and Research in Science Education

There are many problems in science education which we are facing today and there is an urgent need to break away from the conventional approaches and develop initiative in new ways of perceiving and defining the problems.

Science teaching is a complex task and to make it meaningful there is a necessity to give to it the research support. The research findings will provide additional dimension to modify class room teaching and to meet the challenges. There is an imperceptible but unmistakable link between the quality of research and the quality of teaching. The researcher who is engaged in determining new perspectives will definitely influence teaching by his findings. It is understandable that research is helpful in determing the effectiveness of developmental programmes in use or in progress. It is also possible to seek answers of unresolved problems in science teaching.

Thus, there are many functions of educational research helping thereby the teacher in the class room instruction. Tyler (1965) has long back mentioned some functions of educational research which are also applicable to science-education research. These functions are as follows —

(a) Provide answers to operational questions

(b) Assess educational programmes, practices and materials

(c) Build up a body of information about educational enterprises

(d) Provide the out-look, stimulation and guidance for educational innovation

(e) Develop more adequate theory about educational process

Thus the purposes of science education research are varied and they seek answers to the problems related to learning in science. There are many variables which interact with one another and influence teaching and learning. Wanchoo (1976) has very aptly described it as follows:

"School education is a multidimensional system. It depends on a large number of factors which impinge on each other. Each factor has its own growth rate and level, operating under several constraints in this country. Dimensions are, students, teachers, facilities, academic set up, and administrative set up .. ... If the aim of educational process is to shape the personality of a child so that he can serve his future needs, can contribute to the needs and development of the community and the nation of which he is a part, and can learn to be an alert learner all his life, the interrelationship of various dimensions and their factors operating in a class-room as well as outside it, must be studied adequately. Hence the need for educational research."

It is evident that research in science education stems from the psychological implications to teaching and learning, teaching methods, teaching practices, curriculum development, and evaluation. Very recently, renewed emphasis has been laid on the philosophical studies, sociological studies, and the historical studies concerning the nature of teaching and learning process in science. A significant publication of the School Council in Britain, titled, "Changes in School Science Teaching" (1970) has observed that research problems should be related to the growth of intellectual level among children and its relationship with the learning of science. It was also suggested that there should be renewed emphasis on the methods of teaching and learning science. In this context the following areas were delineated

1. Investigations of the relationship of general intelligence and more particular forms of ability to science aptitude and achievement.

2. The acquisition and use of science concepts.

3. Intellectual development during the school years and its relationship to science learning.

4. The formation and use of analogies and models in science teaching.

5. Studies of different methods of teaching science-particularly in relation to thinking, problem solving and the promotion of the inquiring mind.

6. Studies related to the role of curiosity, interests, and attitudes in learning science.

Priorities in Science Education Research

There are varied and significant areas of science education which demand immediate attention of the researchers. Unfortunately little has been done in the field of science education and much remains to be done. In existing conditions research programmes depend on two vital factors, namely, needs of the schools and the availability of the expertise. Fortunatelly another significant element, viz. financial aspect, has been solved by the National Council of Educational Research and Training as well as other agencies by providing sufficient amount for educational research.

For science educators this is the most appropriate time to consider the worthwhileness and usefulness of science education-research in the light of national needs and the direction in which the national thinking is going on. To map out the format for science-education-research, there is a need to focus the attention on the priorities of research, based on the social needs, and the requirements, to implement new education successfully. The inclusion of science and mathematics compulsorily in ten year schooling is an indicator that we have accepted that :

1. Education has to be related to life, needs and aspirations of people and it be an instrument of social change.
2. Education should help in preparing scientifically literate citizens.
3. Science is an armamentarium of a mind coping with modren technological society.
4. Science is to be taught heuristically for developing rational ability and scientific attitude.

Many areas of science education are unexplored and need immediate attention of the workers On priority basis we have to select the areas which reflect complementarity of research and development Some of the important areas of science education research are as follows .

1. Science and social relevance
2. Science and productivity.
3 Scientific literacy
4 Science as an instrument in developing rational abilities.
5 Possibilities and effectiveness of integrated science/environmental science/discipline approach.
6. Applying the ethos of science to change rural, traditional value system
7. Teaching science in rural areas and identification, nurturing of talented science students from these areas
8 Teaching science to socially and economically deprived children
9 Using non-formal agencies to apply science in changing traditional attitudes or in creating scientific temper or in spreading scientific literacy
10 Preparation of science teachers for primary and secondary education.
11. Developing scientific humanism.
12. Encouraging multi-disciplinary research in science education.

It is high time to discard traditional research which is attempted only for the sake of research. Whatever the situations or explanations may be, the research in science education should be effective in creating useful changes in nation's classrooms. "Science education should be concerned not only with research but also with the engineering of research so that it can be translated into active use in the classroom." It is evident that research activity if appropriately planned and honestly conducted, can lead to increased clarity of thought and it will also be a humanizing experience for the workers in the field. [4]

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2

Science Education Research In India : An Analysis

J. K. Sood

Today, science education confronts with many problems and responsibilities. Some of the problems in science education are : how to develop scientific concepts, how to prepare science curricular materials, how to generate social awareness about science and scientists, how to nurture creative talent in science, how to evaluate learning and teaching in science, etc. Some of the responsibilities of science education are related to relevance, accountability scientific literacy, determining the actual state of knowledge in science education, improving the stature of the field, determining the location of the frontier, determining the structure of science education, generating the theory of science education, and humanizing science education. In India, responsibilities in science education are much more than the problems because this field is new and much remains to be done

The Nature of Science Education Research

The responsibilities and problems in science education necessitate continuous efforts to improve teaching methodology, curriculum and school environment. One of the tested means to find solutions of these problems is to renew research efforts in science education. Those who are concerned with research in science education, should try to determine its elements and their influence on pupil learning. If we come closer to the realities of research in science education, we have to determine the areas of research in science education and then to indicate the problems that arise in each of them.

Research in science education is a systematic study of problems that are related to the learning and teaching of science. Science education is an area where interaction between behavioural sciences and natural sciences takes place. Therefore, science education research is interdisciplinary and a researcher applies pedagogical principles in the learning and teaching of natural sciences. As science education is a hybrid of the social and natural sciences, a researcher should possess understanding of both, natural sciences and social sciences.

Current Research in Science Education in India

In India, educational research has been analyzed by Adaval (1968), Ahluwalia (1973), and Buch (1974). All these authors have included science education studies in their review, as its integral part. Recently, Wanchoo and Raina (1976) have analyzed science education research, conducted at the M.Ed. level in different universities. There is no single study which presents a "whole" view of science education research in India. Science education research in India is carried out mainly by the educational agencies, colleges of education or the universities, and individual scholars.

Some of the important researches in science education have been conducted by the National Council of Educational Research and Training, All India Science Teachers' Association, State Institutes of Science Education, and Board of Secondary Education in different States. These agencies have attempted research in the form of developing science curriculum, preparing science text-books; developing instructional materials or science kits, and preparing new techniques of evaluation. It means most of the research attempts were of "developmental" and "service" functions.

Researches for the purpose of degree have been undertaken at the Ph. D. and M. Ed. levels. The attempts at Ph. D. level are mostly on determining scientific aptitude and achievement in science. Some researchers have worked in the area of science curriculum. Saxena (1960), Gupta (1962) Roop Prakash (1968), Seth (1967), and Bountra (1970) tried to develop and standardize attainment/achievement tests in science. Dave (1964), Despande (1967), Venktaramana (1970) developed aptitude tests for science.

Kelkar (1950), Patole (1967), Veerappa (1958), studied or developed science courses.

Sen-Gupta (1963), Baquer (1965), Nayar (1971), and Pathak (1972) determined factors differentiating high and low achievers in science. Sood (1974) has studied attitudes towards science and scientists. Vaidya (1974) has studied some aspects of thinking among science students of adolescent age.

At M Ed level, approximately 335 Studies have been Conducted in mathematics and 255 in Science education. An exhaustive analysis has been attempted (table I) in the book *Research in Science and Mathematics Education* (Wanchoo and Raina, 1976)

TABLE I

Areas of Research	Total No. of Studies
1 Mathematics Education	335
2. Science Curriculum	36
3. Methods of Teaching Science	14
4 Instructional Material	41
5 Science Evaluation	156
6. Preparation of Science Teachers	8
Total	590

Individual scholars have carried out many studies. Some of the examples are as follows .

1. Survey of Physics Teaching in Rajasthan.
2. Mathematics and Science Education in Indian Schools
3. A relationship between Attitudes and Achievement in Science

An Analysis

Researches attempted in science education have been analyzed in this paper. Most of the studies fall in one of the following categories :

1. Developmental studies
2. Survey Studies
3. Test Construction/evaluation
4. Different methods of teaching

Developmental and survey studies were of great significance for a country such as India. It was possible to determine the existing status of affairs and to prepare curricular materials The curricular materials prepared by the N.C E R T A.I S.T A and Board of Secondary Education, are of great utility. Development of science text-books for primary and secondary school stage preparation of instructional materials, and new evaluation techniques, were the most promising attempts It will be proper to realise that most of the science improvement efforts were not started as research studies, but operational programmes, reflecting the philosophy and rationale of new science curricular materials developed in advanced countries These programmes are now getting indegenous flavour and systematic new approach.

Most of the science education research has been conducted by the degree students. "Such research is necessarily hurried and harried."[9] These studies are done for the purposes of degree and than forgotton, without using it.

Approximately twenty five percent of the studies are fact finding surveys and lacks generalization.

More than forty per cent of the studies are related to the development of achievement test. At the Ph D level, this percentage is much higher.

Some of the studies have examined opinions about values, objectives, courses, equipment, and text-books. These studies are not attempted under any theory.

Some of the studies have compared different methods of science teaching without any conclusive evidences in favour of one or the other method

There is a dearth of longitudinal studies, spread over a sufficient span of time

Some initial attempts have been made in the area of creativity in science, understanding of the nature of science attitudes towards science, and Piagetian thinking.

A critical study of one hundred dissertations by the author shows that research in science education is fragmentary, atheoratical and each research effort appears to be a separate effort and it is difficult to generalize the findings of different studies.

Kempa (1966) has recorded some observations on science education research which is true in this case also As such the criticism is as follows .

1. The absence of an adequate theoretical framowork underlying much science education research
2. Methodological shortcomings in the design and the execution of research studies
3. Inadequate attention to science-specific problems of learning and to the characteritics of the science learner.

There are no efforts to develop models and theories of science education. There is dearth of suitable instruments needed to conduct evaluative studies, measuring cognitive, affective, and psychomotor aspects of learning It appears that researchers are not prepared thoroughly in the understanding of the academic fields in science education, psychology of learning science, application of research techniques and statistical methods in science education research.

Main Areas of Research in Science Education

With the emergence and development of new areas in education, the range of topics of study as well as the techniques used have widened. Thus, studies concerned with child development, sociology of science, nutritional deficiency and learning, brain development and learning, learning and cultural impact are some of the areas which need research attempts with more vigour and increasing frequency. Some of the other areas of research in science education may be attempted on priority basis. These areas are as follows

I Learning Science

(a) Concept formation in science.

(b) Piagetian application and concept learning.

(c) Psychological considerations for teaching and learning of science,

II Teaching Science.

(a) Strategies of teaching/Methods of teaching science

(b) Teaching Style.

(c) Classroom interaction and learning of science.

(d) Micro-teaching as a method for preparing science teachers.

III Curriculum in Science

(a) Curriculum development in Science.

(b) Science text books and instructional materials in Science.

(c) Science Curriculum evaluation

IV Evaluation in Science

(a) Evaluation techniques for measuring different aspects of learning

(b) Preparation of evaluation instruments

V Miscellaneous

(a) Development of models/theories in science education

(b) Nurturing the creative talent in science.

(c) Measuring social aspects of science

VI (a) Sociology of science

(b) Sociology of science education

Planning for the Future

An analysis of science education research indicates that it has been guided by generalists in education or psychologists. Science education research in India, is in its infancy and science educators have to build traditions of reseacrh. In Colleges of Education, science education is generally equated to methods of teaching science and in its stature it is always subordinate to psychology. Science education is to be established as a seperate subject. Hurd (1971) has very aptly said,

> My first plea is that we need to establish more concisely a theory of science teaching, a philosophy, a rationale, a normative statement, a point of view,

what ever term you prefer to use We can contribute to the improvement of our field by exposing our educational theories to philosophical criticism

It becomes evident that science education research should be based upon a theory or a model to minimize the weaknesses of research so commonly committed by the researchers in an absence of a model. According to Gage (1963) a well designed model helps to clarify the factors that have been isolated for investigation. If the relationships among factors are presented in graphic or outline form, the dynamic state of the model can also be represented

In India, both, elucidatory research as well as evaluative studies are needed. These attempts will prove useful in establishing the theory or paradigm of science education and will prove the efficacy of the science programmes launched in the country.

Developmental programmes and research should go together. These are complementary to each other and shall make research operational

Imaginative and bold research designs should be encouraged which will help the researcher to investigate the interaction of factors that both facilitate and interfere with the learning of science.

We should improve the research competencies of science educators Research competence should help in solving many problems with all imagination and systematic research methodology. M. Ed. science education course should also be improved in many aspects.

Science education research should be a collaborative effort among

(a) researchers from natural sciences, science educators, sociologists, and psychologists,

(b) Colleges of education, State Institutes of Science Education, and Board of Secondary Education,

(c) Science educators and science teachers.

(d The N C E R T. and the Professional organizations

Science education research shall be synthesized regularly and it should be diffused effectively Here, it will be useful to mention the efforts made by the Teachers' College of Columbia University and E R I C. at the Ohio State University, which have published all researches attempted in science education in the last hundred years There is a hope that such attempts shall have multiplier effect on Science Education in India. Howe (1966) has very correctly suggested that science education should be concerned not only with research, but engineering of research so that it can be translated into active use in the classroom

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3

Research in Mathematics Education : An Analysis

G. M Bhardwaj

During the last fifty years Mathematics has developed new concepts as well as a new meaningful language. The Secondary School mathematics is the basic structure on which the whole superstructure of Mathematics, Physical Sciences, Social Sciences and Technology in the Universities and technical institutions rests. Therefore, it is desirable that the new meaningful language of mathematics should permeate to the Secondary School level. As the requirements of the subject have been changed, it has become necessary to rethink on the secondary school mathematics

The nature and the chief Characteristics of mathematics such as abstractness, precision, generality, logical nature etc should influence the teaching of secondary school mathematics In these classrooms the mathematics has too long been taught by the rule of thumb methods. It has almost been taught as mechanics is taught to an uneducated person in a motor workshop But the new points of view are new [illegible] in mathematics have provoked a revolution in many countries during the past decade. The significance of modern mathematics as a part of our scientific culture has been established. It represents a way of thinking that should be understood by our secondary school teachers. These responsibilities and problems of mathematics education necessitate continuous efforts to improve teaching methodology, mathematical understanding, evaluation in mathematics, mathematics curriculum and the functional thinking in mathematics. Only research in mathematics education can give us guidelines for improvement of the factors mentioned above.

An attempt has been made in this paper to review the researches in Mathematics Education in U S A ,U.K and India.

Research in Mathematics Education in U S A

Research in mathematics education has been characterized by Romberg (1969) as large in quantity, poor but improving in quality, and diverse. Over a thousand of mathematics instructions have been reported. The poor quality of most of the studies has been attributed to too much interest in mathematical component, and too little concern for experimental design, measurement, or analysis.

The research reports have been categorized into the following eight areas: (1) Mathematical learning from an association learning framework. (2) mathematical learning from an activity learning fremework. (3) mathematical problem solving-a creatize behaviour, (4) mathematics teaching; (5) the effectiveness of instructional programmes, (6) the association of learner characteristics with mathematical achievement, (7)attitudes towards mathematics, and (8) the evaluation and measurement of mathematics achievement.

These relations reflect the stimulation of mathematics education by the new curricula developed in the early 1960's and the growing interest and involvement of mathematics educators and psychologists in systematic studies of the learning and teaching of mathematics. There is considerable agreement about what should be taught but not about how it should be taught (Begle, 1968).

Studies in mathematics education in U.S.A. can be classified into three classes: (1) Studies related to the effectiveness of instructional programmes; (2) studies related to learner's aptitude and abilities in mathematics learning, and (3) studies related to evaluation and measurement of mathematics achievement.

Studies Related to the Effectiveness of Instructional Programmes

The products of curriculum reform movement made the most obvious contribution to changing educational processes. Variety of studies (descriptive, comparative, experimental) have been undertaken in the field of effectiveness of instructional programmes. These studies are numerous but are of poor quality. The major reason is that the researchers were primarily interested in the quality of the instruments or the ingenuity of the technique and not in the changes in behaviour produced.

While evaluating the instructional programme, Davis (1965) simply described the diversity of classroom activity, the amount of active student participation, and the creative classroom experiences as evidences to support the effectiveness of the third and fourth years of Madison Project. [illegible] (1967) examined the effect of a [illegible] mathematics in teaching disadvantaged elementary school children

He expected the scholar to communicate advanced notions of mathematics to the children and to arouse their interest in school work. Pollack (1967) reported the results of a study on the use of the S.M.S.G. (School Mathematics Study Group) set of films and accompanying text to retrain elementary school teachers. Cronbach (1963) challenged developers to gather descriptive data during development by systematic procedures, subsequently called formative evaluation of the product. Expository studies by Coulson (1964), Romberg and Rowelon (1969) reported the use of formative procedures in developing instructional programmes.

Comparative evaluations made on data from the experimental and control groups, were done by Biddle (1967)and Berger and Howitz (1967). Some studies such as that of Hungerman (1967) and Graft and Ruddel (1968) in this category (comparative) compared the effects of 'modern' and 'conventional' programmes over longer periods of time

Supper and Binford (1964) and Herriot (1967) evaluated the relative effectiveness of a programme in quite different population of subjects

In experimental studies for comparison of instructional programmes, researches have attempted to control such factors as teachers or procedures Comparing 'modern' and 'conventional' programmes Eriksen and Ryan (1966) controlled for the teacher effect while Armstrong (1968) controlled for teacher, instructional method, curriculum organization, classroom environment, media, and five linear variables.

Weaver (1966) reviewed, the effectivensss of Various organizational procedures for the teaching of mathematics at the elementary level.

Studies Related to Learner Aptitude and Abilities to Mathematics Learning

The psychological area of individual differences has been described by Stolurow (1965) as an "Ugly iron curtain". In contrast to the large volume of Curricular studies, only a few studies have been done recently on identifying mathematical abilities. The studies in this field include studies done by Swedish psychologist Werdelin on mathematical ability (1958) and geometrical ability (1961).

Hedley (1965), Westbrook (1965) and Feron and Kim (1966) have studied the factors affecting mathematical ability. Relationship between mathematics and reading ability has been studied by Smith and Heddens (1964), Kane and Hater (1968), Call and Wiggin (1966) and Gilmary (1967).

Although many investigators studied attitudes towards mathematics, evidence to support the claim of improved attitudes is still meager a decade after the new programmes were introduced. Aiken (1969) prepared a careful critical review of 99 studies on attitudes towards mathematics.

Studies Related to Evaluation and Measurement of Mathematics Achievement

Test construction in mathematics on the basis of classification of objectives similar to that outlined in Bloom's Taxonomy has been done by Epstein (1968), Romberg (1967, 1968) and Romberg and Wilson (1969). Wood (1967) has developed an item [illegible]

Research in Mathematics Education in U. K.

The main research emphasis in mathematics education in U. K. continues to be on the syllabus and the curriculum at both primary and secondary levels.

At the secondary level the Mathematical Association (1968) analysed the syllabuses of the 12 major British Curriculum Development Projects and showed that although there is a marked disagreement over the sequencing of the content, there has been various attempts at devising means for enabling teachers to plan Curriculum sequences, and good examples of these are by Lister (1970) and Vaughan (1971) using flow diagrams and network-analysis respectively. But there is an obvious need for more structural research on the implications of adopting various types of sequencing. One example of this type of research is that of Armstrong (1969) who compared *topic spiralling* with *area spiralling*. Spiralling whether of topic or of areas is am approach towards solving the problem of how to determine a one-dimensional track through the multi-dimensional field of mathematics.

Another research area concerns the individual child and his learning, and here one can see a trend towards identifying those abilities which are important in being able to perform mathematically.

There has been little research concerned with verifying Piaget's theory, compared with the heavy emphasis on this in the early 60's. Sullivan (1967) and Fogelman (1969) have carried-out an analysis of Piaget's contribution to education. More structured researches by Fogelman (1970) and Bryant and Trabasso (1971) have shown the dissatisfaction which many feel regarding the uncontrolled nature of much of Piaget's work. Bruner's ([illegible]) critique of Piaget's "The Growth of Logical Thinking", is still relevant and makes interesting reading here, and it seems likely that more research results will appear soon. In the same area Skemp (1971) offers the latest developments in his schematic learning theory which should show the secondary teachers that not every psychologist is concerned with primary age children.

A trend is seen by the increase in interest for the idea of mental abilities. The researches of Birkhouse (1967), Law (1969), Richards and Bolton (1971), Rao, Penfold and Penfold (1970) and Fogelman (1968) were all concerned with the relationship between mathematics and various mental abilities. Land and Bishop (1969) followed on the work of Mc Farlane Smith (1964) with a series of experiments concerned with the visual abilities and mathematics teaching. They consistently found that spatial ability and mathematical ability were highly correlated, and showed how their abilities could be developed, by carefully chosen structured materials,

The third main area of research activity in U. K. is the teacher and his methods. This area has received slightly less attention than the others.

Biggs (1967), Land and Bishop (1969), Dean (1970), Orlov (1971) have explored the *mode-presentation* method variable while Richards and Bolton (1971), Takuba (1971) and Land and Bishop (1969) have investigated the *sequence* method variable. Wheeler (1970), Goutard (1968), Wittman (1969) and Hirst (1970) have exemplify the change in emphasis from teaching mathematics to helping pupils develop. To use Bishop and Levy's (1968) Categorises of teaching behaviours, they are concentrating on techniques (of strategies as they are sometimes referred to) rather than on methods with the emphasis on the individual teacher's decisions involved Bishop (1970) has considered the decision-making model within the context of teacher training, and Barnes and others (969) have carried out some facinating (and non-quantified) analysis of classroom-interactions. Interestingly, also whereas the emphasis in the U S A. seems to be on quantifying aspects of the classroom interaction, here the focus is on the quality of the interaction

Research in Mathematics Education in India,

Research bearing on Mathematics Education in our Country is neither sufficient in quantity nor commendable for quality. The bulk of the work falls into the category of studies which bear indirectly on the methods of teaching There have been a total number of 335 studies in mathamatics education at the Ph. D and the M. Ed levels in all the Indian Universities from 1939 to 1966. This number also includes the studies completed in Rajasthan and Kerala Universities upto 1973 The number of studies conducted at the Ph. D level is only two.

Research studies in the field of mathematics education have been taken up by thirty one Universities in India during the period 1939 to 1966 The number (31) looks promising but when we analyse the studies, we find that in only 11 universities the number of studies in this area of mathematics education is abovt 10. The highest number 44 is from Madras University, which tops the list.

One of the requirements of the M. Ed. degree in the Indian Universities has been the submission of a report or a dissertation as partial fulfilment of the degree Barring two Ph.D thesis, research studies conducted at the M Ed level alone are available The investigators mostly beat on common problems in the field of mathematics education. Studies conducted by the students of M Ed having mathematics background have been classified in various areas. Achievement, Diagnosis, Mathematics Teaching, Backwardness, Failure and Evaluation, Curriculum, Mathematical Understanding; Text-books and Teaching Aids Attitude, Achievement and Socio-Economic Status Attitude Towards Mathematics, Interest, Intelligence and Achievement, Professional Preparation, Status of Mathematics, Functional Thinking, and Contribution of Indian Mathematics Some of these studies often end with the enumeration of errors or the causes or various difficulties without proceeding to arrive at any perceptive conclusions or suggestions touching on the basic reasons Very few experimental studies have been carried out. These are mostly of the action research type and cannot be considered significant contribution to the theory of teaching mathematics. As the context of mathematics is universal unlike that of some other subjects, duplication of research could have been avoided, but unfortunately, most of the research scholars in one University seems to have been unaware of reseaech developments in other Universities in the country. Attempts to integrate the findings are, therefore, rare and no studies can be traced which try to rest conclusions to earlier work. Many of the studies constitute random attempts and adopt a fragmentary approach to the problem of teaching mathematics.

Trends And Gaps In Research in Mathematics Education

Speculations about what will happen in future are always difficult. However, by projecting work of the researchers in the field, certain trends become apparent.

In U. S. A. the largest percentage of recent studies are Ph. D. dissertations the number of these is increasing every year. Summers (1967) reported 75 Doctoral dissertations in mathematics education in 1964, Mangum and Morris (1969) found 97 theses in 1966; and Weaver (1969) reported 157 theses for 1968. In India barring two Ph. D. thesis, research in the field of mathematics education has been carried out only at M. Ed level in the form of M. Ed. dissertations. In all 335 studies have been completed in this area during the period 1939 to 1966.

Romberg (1969) has visualized four trends in progress of mathematics education research: (1) there will be more programmatic research, (2) there will be better curriculum evaluations, and (4) there will be better tests developed for use in mathematics education. The research in the area of mathematics education in India projects the following Conclusions

(1) The quantum of research in mathematics education in general and that at the primary level in particular, is very meagre. However, in recent years, comparatively a greater interest seems to prevail over research in problems of mathematics education at the primary level.

(2) The quantum of research in the area of testing is comparatively large but in areas such as history of mathematics, professional preparation of teachers development of mathematical concepts etc. is negligible. Undoubtedly testing is an important area but too much importance given to it seems to have adversely affected research in other sectors.

(3) The quantum of experimental studies in almost all areas of research such as curriculum, methords and

techniques of testing, preparation and use of instructional material including text-books and teaching aids, psychological aspects of learning mathematics, and so on, is practically negligible. Except one study in the area of methods and techniques of teaching, all others belong to normative type

(4) Research in areas such as programmed instruction, mass media communication, etc , do not come under the purview of research at all

(5) Although behavioural problems in mathematics classesare quite common. There is only one study, 'Cheating in Mathematics Classes' that has been taken up.

Thus research in Mathematics Education is vitiated by several ills. Very few people in the field of research attempt to realize the need for research in this area but this does not prove that our researcher are incapable to do research in mathematics education.

Suggestions For Further Research

A special effort has to be made in future to carryout rigorously designed research work in mathematics, and care should be taken to determine the effectiveness of various teaching methods which are practised at present and to ascertain their applicability according to individual differences in pupils. New methods are required to be tried out in all the areas Research work pinpointed on specific topics rather than 'general' should become the pattern.

In the light of the above observations, a few suggestions for improving the existing conditions are offered·

1. Research in mathematics education at the secondary

and primary level should be developed.

2 Research areas may be developed with a particular reference to mathematics education in the areas such as : Analysis of instructional process, Techniques for effective instruction, Supervision of instruction; and Pr-service and in-service training for teachers at both levels.

3 As research should stimulate and cause innovations greater proportion of studies of experimental type may be conducted atleast for a few years to come.

In this context, the following areas of research in the field of mathematics education are suggested where the research scholars at the Ph D and M. Ed. levels may work.

1. Development of syllabus including topics from modern mathematics, both for Primary and Secondary levels.

2. Preparation and use of instructional material, work-books, hand-books, text-books and other teaching aids.

3. Preparation and use of programmed materials.

4 Effective use of mass-media Communication.

5 Development of mathematical concepts.

6. Effective teaching of Mathematics.

7. Processes and techniques of teaching of Mathematics.

8. Professional preparation of teachers.

9. Aims and objectives of Mathematics and Mathematics education.

10. Learning experiences of the pupils at various stages of education.

11. Procedures and problems of evaluation of various facets of mathematics education at micro and macro levels and their follow-up.

12 Determination of objectives of teaching mathematics at : Primary, Middle, Secondary, Higher Secondary, College, and University levels

13. Spelling out the social, cultural and Economic factors that influence the determing of the programmes in mathematics.

14 A Study of interdisciplinary give and take of mathematics

15. Contents of question papers: A critical study

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Part II Science Curriculum Evaluation

4

Formative and Summative Evaluation Of Science Curriculum

J. K. SOOD

There are many prescriptive curriculum theories, based upon the ideas generated by intuitive procedures or by the consensus of a group of people. Similarly, there are many curricular projects which have produced a good variety of instructional materials based upon sound pedagogical principles. It is true that most of these programmes provide sufficiently rich mechanical knowledge about science and humanities. But these materials are yet to be tested on scientific rigour to answer questions of accountability; learnability and teachability. One of the most pertinent question is : How far particular curricular materials help in generating humane environment where learners develop self-actualization behaviours with the help of teachers ? It is expected that these materials should prove helpful in developing self-regulating, decision making abilities based upon rational thinking It appears to be very ridiculous that an addition of just one topic or subject to the already existing syllabi make it innovative and effective. Let us think hypothetically, that the inclusion of yoga or Health Education as a compulsory school subject, will make curriculum effective How far such efforts will prove efficacious without proper feedback or research support ? The logic of such efforts appears to be self defeating in nature Similarly, there are alternative project materials available for use. But the question is How to choose from the available alternatives ? It is not easy to establish the superiority of course 'A' prescribed or developed by a particular educational agency over course 'B' developed by another educational body

All these questions need sufficient emperical evidence to prove the effectiveness of particular curricular materials, and curriculum evaluation is the most appropriate answer

How much change has occured since Independence.

Since independence school curriculum has undergone complete metamorphosis Efforts have been made to make it relevant to the contemporary life and meet the needs and aspirations of people. These changes have been initiated at three levels, namely, at the National level by the National Agencies, at the State level by the State Board of Secondary Education, and by the Professional Organizations In 1948-49 University Education Commission demanded a change in school curricula while discussing the University Education System in India. In 1952-53 Mudaliar Commission presented a scheme of multipurpose schools to meet the demands of ever increasing heterogeneous school going population. Consequently, many of the school were changed from single track to multipurpose schools In 1955, the All India Council for Secondary Education assisted the States to bring a change in school curricula. In 1959 Harper Committee putforth many valuable suggestions to make school curricula meaningful and relevant. Most of the changes have come through the National Council of Educational Research and Training, since its inception in 1961. Similarly, Education Commission (1964-66) suggested significant changes for the improvement of school curricula. Unfortunately, the implementation was not adequate and most of the efforts for improvement were related to updating the content, erasing the content errors, changing the order of topics, and adding a few new topics. In some of the states objectives of a particular subject were determined alongwith certain changes in the syllabi. Most significant change was in the from of preparing new text books. This effort was made by the National Council of Education Research and Training through national panels of text book writers,

It is easy to generalize that there was on fundamental change and most of the changes were not based upon research evidences. Surprisingly, the changes were not based on any assessment of the school curricula.

Concept of Curriculum Evaluation

It is essential that the curricular materials should be evaluated to ascertain the feasibility of the objectives and the usability of the materials. Such efforts will provide an informational source on the promise and progress of curriculum innovation and will be helpful in assessing its own effectiveness.

It is sufficiently clear that evaluation is not just testing or the analysis of test results. Nor is evaluation simply a proclamation of good, bad. The final act of evaluation is oncerned with a judgement of worth, of value. Comming to curriculum evaluation, it is also concerned with the judgement of value and of worth. Hand (1969) has mentioned, "Curriculum Evaluation" is a value weighted interpretation of goals, objectives, subject matter, teachability and learnability of materials and costs in time and effort."

Contemporary educational research mentions that curriculum evaluation is a process of delineating, obtaining, and providing careful information for judging alternatives (Stufflebeam, Daniel L; etal).

Similarly, Scriven holds that, "evaluation is a methodological activity which....... consists of simply in the gathering and combining of performance data with a weighted set of goal scales to yield either comparative or numerical ratings, and justification of (a) data gathering instruments, (b) the weightings, and (c) the selection of goals."

Other workers in the field record that curriculum evaluation is concerned with, determining validities of the course and its potential upon the individual and the society."

For the purposes of this paper, it can be generalized that curriculum evaluation helps the curriculum planners to judge the efficacy of the materials produced and their impact on students in the terms of goals and aims specified. Curriculum evaluation also seeks to provide a basis for making decisions among alternatives (Hemphill, 1967). It means curriculum evaluation is helpful in improving the course based on proper feedback and it provides basis for selecting the proper materials from the available alternatives.

Process of Curriculum Evaluation.

Generally, curriculum evaluation is attempted when the curricular materials are in the final form, namely product

In india, this final form is a text book. Rarely trial editions are prepared and tried out to get feedback Unfortunately there are no research evidences in India where curriculum evaluation has been done. Whatever has been attempted it is in the form of a "Critical Study of a School Syllabus," which is just theoretical

It is true that the concept of curriculum evaluation is not very old. Its recency is illustrated by the fact that the objective evaluation of curriculum, for the first time, as a separate entity, was mentioned in the Encyclopaedia of Educational Research, 1969(Robert Ebel, (ed)1969) "In many respects the systematic evaluation of curricula is only beginning to emerge as a recognizable field of educational research " Objective evaluation of curriculum has emerged from the discussions of Chronback, 1963, McDonal Raths, 1963, Hastings 1964, Scriven 1965, Ausuble 1966, Grobman, 1970, Welch, 1969 etc. The writing of the workers in the field have accepted curriculum evaluation as an integral and fundamental part of curriculum development, not as an appendage, and it should be attempted in a systematic way.

Scriven (1967) has coined two terms Formative and Summative, to describe two types of curriculum evaluation. Formative evaluation refers to the judgement of the material while it is in the making. Here efficacy of the material is judged in terms of teachability and learnability as well as the objectives laid down for the specific course. These findings are helpful in the improvement of the materials at the developmental stage, that is formative evaluation directs a programme developer "back to the drawing board"

Summative Evaluation is a systematic attempt to determine the attainment of the objectives of the programme as laid down at the initial stage It also helps in judging the best programmes from the available alternatives.

Evaluation of the complete programme is further named as macro-evaluation, if all produced materials are evaluated in its totality. If there is dearth of money and time, micro-evaluation is suggested, where small segments of the curriculum are evaluated.

Examplars of Curriculum Evaluation Studies

It is not very easy to evaluate curricular materials in terms of the gains which childern have earned and the specified objectives of the programme In relation to science courses there are a few questions What should be the criteria which can be specifically used to evaluate particular science curriculum ? How effective are these science curricula in terms of teaching and learning ? How far a particular curriculum in science leads children to achieve proposed purposes of science teaching ? There are some examples which have given a line of action in this area of research. Michallis, Grossman and Scott (1967) have attempted theoretical evaluation at the Science Curriculum Centre, University of Okhahama (1972) and developed a criteria. An adopted form of this criteria is as follows.

1. Does the material reflect proposed aims of science education ?
2. Does the material reflect process of science, facts of science, and social aspect of science ?
3. Dose the material reflect specific objectives ?
4. Does the programme has a conceptual frame-work ?

5. Are conceptual themes used as the basis for organizing the content ?
6. Is the programme balanced in terms of over-all sequence and content coverage ?
7. Does the programme match developmental levels of children as discussed by Piaget ?
8 Are models of enquiry indentified and incorporated in the programme ?
9. Are the students involved actively in learning ?
10. Does the progamme provide variety of learning activities, suitably matching interest and ability of children ?
11. Does the programme provide sufficient opportunity to develop individual creative potential ?
12. Does the programme develop positive attitudes towards the discipline, and scientists ?
13. Does the programme reflect the proper use of theories of learning and ideas of instructional objectives ?
14. Are teaching strategies consistent with the style of thought and way of enquiry used by scientists ?
15. Is evaluation an integral and continuing part of instruction ?
16. Is on-going revision implicit in the curriculum ?]

Welbresser (1968) has taken a different position on curriculum evaluation. His experience is based on the evaluation of the Primary Science Project–Science–A Process Approach. He contends that the assessment of the effectiveness programme should be based upon behavioural objectives. In this approach curriculum should reflect the expected learning outcomes in terms of reliably observable behaviour which is measurable. Welbresser holds that curriculum evaluation procedure should satisfy the following .

(a) Measuring the proposed aims of the curricular project.

(b) Each asessment task should be acceptable to the curriculum developer as an evaluation of a particular objective.

(c) Reliability and validity of data gathering instruments.

Tuckman (1972) has supported and reorganized the approach putforth by Welbresser This approach comprises the following five steps.—

1. Identification of the aims and objectives of the programme
2. Restatement of aims and objectives in behavioural terms.
3. Construction of content valid test to measure the behaviourlly stated aims and objectives
4. Identification and selection of a control, comparison, or criterion group against which to contrast the test group.
5. Data collection and analysis.

Sanders and Cunningham (1973) have presented a framework appropriate for discussing and organizing formative evaluation studies in product develoment.

The framework is two dimensional, with formative evaluation activity constituting one dimension and sources of information constituting the other. The formative evaluation activity comprises four stages pre-developmental activities, evaluation of objectives, formative interim evaluation, and formative product evaluation Three major sources of formative evaluation information have been identified as follows:

1. Internal information that can be generated by inspecting the product itself
2. External information, information concerning the effects of the product or its components on the behaviour of students, teachers, and parents.
3. The third is contextual information concerns to the conditions under which materials are expected to function.

Hurd (1969) has developed a criteria to evaluate curriculum, which is as follows

1. Course content validity : This valitudy depends on the basic concepts of science, their organization, structurre and proper emphasis on investigatory and conceptual phases of science
2. Pedagogical validity Suitability of the materials concerning particular age, effectiveness of teachability and learnability. The course shou'd sustain the interest in learning and motivate children for learning.
3. Sociological and Philosophical Validity . This aspect discusses the relationship of science and society. Curricular materials should develop functional understanding of this relationship among the students.

Another example is available from the pioneer study Science Education in Nineteen Countries · An Empirical Study conducted by the International Association for the Evaluation of Education Achievement in 1973. It is based upon the content analysis of the science courses being taught in participating countries (19 in all), cross-national performance tests were devised for four student populations.

This study has used an achievement test, Test on Understanding Science (TOUS) modified form Interest in science Attitudes towards science and Perception of Science Teaching. It is one of the most suitable examples on Science curriculum evaluation where moderation of the more extreme views concerning the use of the mechanistic instruments on the one hand and the impressionistic observers on the other.

Research Studies on Science Curriculum Evaluation

A Survey of the Sixth International Clearing House Report of Science and Mathematic Project (1968) indicated that only 19 out of 68 Science Curricular Projects possessed research evidence of success in achieving stated objectives

Marks (1967) found that students in Chemical Bond Approach Course scored significatly higher on critical questioning in comparison to conventional chemistry course.

George (1965) examined the contributions of three Biological Science Curriculum Study Versions and conventional biology course to increased critical thinking as measured by the Watson Glaser Thinking Appraisal Instrument. The findings were not of significant difference.

In a study employing the Watson Glaser Critical Thinking Appraisal, Heron (1966) found low and average ability students in conventional courses scored significantly higher on one of the five sub-tests, Recognition of Assumptions, than did the CHEM Study groups.

Selch (1969) has recorded that there are several practial problems concerning formative evaluation and summative evaluation. It was recorded that suitable instruments are not generally used for curriculum evaluation purposes.

Most exhaustive analysis of research on evaluation has been attempted by Walker and Schaffarzick (1974) Twenty six studies compared students exposed to different curricula in the same subject on some measure of school achievement

The studies showed a great variety. Twelve of them were in science, five in mathematics, four were in social studies, and two were in English In half of the studies, some criterion measure in addition to subject matter achievement was administered. The authors concluded that the following distinct lines of evidence tend to controvert our initial impression of the overall superiority of the innovative curricula. First, the studies show that the advantage of groups studying from innovative curricula comes entirely from those studies in which the test content bias favours the innovative curricula. Second, that subsect of studies in which two agglomerate achievement tests were used- one biased on either direction shows that traditional curricula more than hold their own in Tests biased their way. Third, that subsect of studies in which the agglomerate achievement test was analysed into presumably more cohernt and unified sub scores show different patterns of achievement on the different components of the achivement measure.

What these studies show, apparently, is not that the new curricula are uniformely superior to the old ones, though this may be true but rather different curricula are associated with different patterns of achievement.

The author of this paper strongly recommends a thorough study of Science Education in nineteen Countries , An Emprical Study, published by I E L in 1973 for an understanding of curriculum evaluation process

It is difficult to mention the name of any science curricular project in India, which has taken formative and summative evaluation as an integral part of curriculum development. Most of the studies are concerned with the evaluation of text books as an end product of curricular efforts. Fortunately, the NCERT has attempted formative micro-evaluation in the form of one or two chapters of a science text book during its writing stage. The purpose was to seek opinion of the science teachers about the adequacy and recency in content. Some researchers have attempted to study a small part of the curriculum, mostly for the degree purposes. Sood and Sengupta (1975) have conducted theoretical evaluation of physics syllabus prescribed by the Board of secondary Education, Rajasthan. This study has also measured understanding of the nature of science and attitudes towards science and scientists. Similarly, Sood (1975) and, Sood and Saraswat (1974) have attempted to measure an understanding of the nature of science among science students studying in eleventh grade.

SUMMARY & RECOMMENDATIONS :

Science curriculum development and curriculum evaluation is not as simple as people take it. Curriculum evaluation necessitates an action line from expertize. Curricculum evaluation models are with us. In the U. S. A different science curricular projects have been evaluated successfully. National Studies have been attempted. In India there is a need to accept this area as an important part of educational research.

It is not difficult to present a case history of a science curricular project as an example. It will be sufficient for this paper to generalize some important considerations required to do successful evaluation.

Most of the researchers and experts on curriculum evaluation agree on three steps for curriculum evaluation First, a specific definition of the product must be made to facilitate the methodology of evaluation This part of curriculum evalution is referred to the goals and purposes of the concerned curricular project. Second consideration is of the means to achieve the stated objectives. It is concerned with the methodology of evaluation or the instruments employed to determine the purposes of the project. Third, the standards or norms used to judge the adequacy of the product be established

Sood (1974) has recommended the use of the following instruments to evaluate cognitive and affective gains of students acquired through an effective science curriculum

1. A science achievement test.
2. Test on understanding science.
3. A science Process Test.
4. A science Interest Inventory.
5. An attitude scale concerning Science and Scientists.
6. A Scale on on Social aspect of Science.
7. Learning Environment Inventory.

The evaluation approach should idclude process studies to find out the actual success in the classroom; proficiency measures and attitude changes, and to find out the changes in the behaviour of children concerning science and scientists.

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Part II Science Curriculum Evaluation

5

EVALUATION OF SCIENCE CURRICULA

Pritam Singh

1.0 Introduction

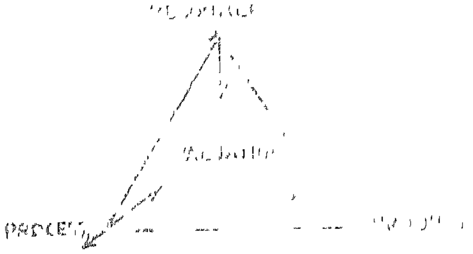
Need for evaluating the science curricula has been felt quite recently. In India scientific evaluation of curricula has yet to take off. This is by no means surprising if we know that the activity of curriculum development itself is seldom a planned and scientific attempt. Whatever the mode of curriculum development may be, need for evaluating the science curricula cannot be over emphasised. Three main reasons for the same are:

1.1 Have the resources been efficiently used to achieve the intended outcomes ?

1.2 Have the new curricula helped the students to acquire the desired knowledge, skills and attitudes for better adjustment ?

1.3 Have the strategies used for development of curricula proved efficacious ?

Thus evaluation of science curricula provides the necessary feedback regarding utilisation of resources, efficiency of the process of development and about the effectiveness of the end product This intimate relationship of evaluation with the resources, process and product of curriculum development can be represented as under



Evaluation of curricula, therefore, has to provide evidence about these three aspects However, process of evaluation has to be determined keeping in view the resources, (financial and man power) the process of curriculum development (style and strategies) and the end products of curriculum (curriculum materials and pupil growth).

2.0 The myth of curriculum development

2.1 Evaluation of curriculum is based on certain assumptions like the following.

- 2.1.1 That the releveant resources were fully utilised
- 2.1.2 That objectives of the curriculum were clearly visualised and stated
- 2.1.3 That content of curriculum was determined in accordance with the requirement of the discipline and needs of the learner.
- 2.1.4 That teaching learning materials and activities were undertaken to achieve the predetermined instructional objectives.

2. 1. 5 That evaluation was considered an integral part of curriculum development etc.

2. 2 In actual practice each of the above assumptions can be questioned on the following bases.

2. 2. 1 Curriculum is equated with syllabus

2. 2. 2 Objectives of curriculum are seldom stated in functional terms.

2. 2. 3 Structure of the discipline is seldom appreciated by the syllabus makers.

2. 2. 4 Teaching and learning is never geared to the methodology of the curriculum (if indicated).

2. 2. 5 Evaluation as a part of curriculum development is seldom considered desirable in a project

In this country syllabus framing, textbook writing, production of other instructional material, judging the effectiveness of teaching and learning, evaluation of pupil growth seldom comes under the purview of the same agency or the curriculum development team. Terms of reference for evaluation of curriculum are thus quite vague, if available at all. In fact the curriculum development is still a haphazard endeavours of a few so called curriculum experts (school teachers generally excluded) who prepare the curriculum within a week's time on the assumptions that old curriculum is bad and the new one must be good. Why the old one is bad or the new one is good, they need not explain to those who have to practise it. Unless this myth of curriculum development is exploded and some rationale or framework is worked out, evaluation of science curriculum would remain a hit and miss affair. If an author of a science textbook can be questioned about the uptodateness of content, if a teacher can be asked to explain or sometimes warned for poor teaching, if a paper-setter can be questioned in a news paper columns about his poor choice of questions for evaluating students in a public examination then why not a curriculum developer be admonished for developing a bad curriculum which indeed is the cause of maladies of all other operations in the educational process

3.0 Curriculum evaluation and product evaluation

When a given curriculum is evaluated it is in a way product evaluation irrespective of the process of development When we want to evaluate a curriculum project, we are interested both in the end products of curriculum as well as the process of curriculum development Therefore, evaluation of a given prescribed curriculum would include the following components of evaluation :

-Objective stated

-Content selected

-Methodology suggested

-Evaluation procedure recommended.

Each aspect is to be judged in terms of criteria developed on the basis of rational judgment of the evaluator or as a result of pooled opinion of experts We can also judge the effectiveness of a curriculum in terms of pupil growth in which case efficacy of the teaching-learning process has also to be judged In fact we have to evaluate the total process of curriculum development Such an evaluation may better be termed as project evaluation in which both the process of development and products of development are evaluated In this type of evaluation aspects like the following have to be considered :

3.1 Planning of the project.

3,2 Development of the materials

3 3 Orientation of teachers and trial of the materials.

3.4 Revision of the materials.

3.5 Training of teachers and introduction of materials

3.6 Diffusion and dissemination of new curricular changes.

3.7 Summative evaluation of the curriculum

3.8 Renewal of the curriculum.

4,0 Variations in curriculum evaluation

Can there be a common pattern of curriculum evaluation? It may be possible only when we have the common concept of curriculum and a centralised curriculum development system. In actual practice, however even this may not be possible, because the financial resources of the concerned agency, technical competence of the evaluators and the time at the disposal of the curriculum agencies condition the scope of evaluation Where curriculum development is a localised affair whether at the state level as in our country or at the institutional level as in U K. or U S A, variations are bound to be there also due to varying assumptions, underlying philosophies, approaches and aspects of curriculum development. Such variations may be attributed due to difference in ·

4.1 Place of evaluation in the frame work of curriculum development.

4.2 Role of objectives in curriculum evaluation.

4.3 Stages of evaluation, reflective, formative, and summative.

4.4 Areas of evaluation.

4.5 Method of collecting evidences.

4.6 Rigour of experimental designs.

4.7 Methodology of processing data.

4.8 Use of evidence in curriculum development process.

4.9 Role and expertise of the evaluator.

Which methodology works better is a question difficult to answer since every curriculum project is born in a different social and educational context with its own assets and liabilities. Nevertheless if the objectives of a curriculum project are clearly stated keeping in view the resources and the philosophy underlying the project, it becomes easier to systematise the process of curriculum evaluation.

5.0 Theoretical framework

Curriculum evaluation is a new venture in this country. There is need for developing a rationale on the basis of which a model for curriculum evaluation may be worked out. For such a rationale certain assumptions are to be identified and implication for evaluation may be traced. Based on these, different components for evaluation and basis for evaluation may be worked out. Following example illustrates this approach with regard to the place of evaluation in the theoretical framework of curriculum development.

5.1 **Assumption :** Systematic evaluation at every stage of curriculum development provides quality control for curriculum.

5.2 **Implication for curriculum evaluation :** Evaluation should be considered an integral part of curriculum development.

5.3 Components for evaluation :

1. Curriculum objectives
2. Curriculum content
3. Curriculum method
4. Curriculum end-products.

5.4 Basis for evaluation :

1. Relevance of objectives and their precise statement.
2. Validity and reliability of data
3. Appropriateness of feed-back of data.
4. Objectivity in judgment making.

6.0 Rationale for evaluation

Assumption	Implication for evaluation	Components of evaluation	Basis for evaluation
6.1 OBJECTIVES			
–When Philosophy underlying a project is made explicit in terms of clearly stated objectives it provides direction for curriculum development	–Effectiveness of curriculum should be judged in terms of objectives which should form the basis for curriculum evaluation	–Product objectives -Process objectives.	-Pupil growth -Quality of materials produced -Utilisation of resources -Effectiveness of strategy -Extent of teacher motivation
6.2 CONTENT			
-Structure of a discipline can be identified and taught	Evaluation of curriculum should be focussed on the structure of the subject rather than on the factual information	-Substantive structure of the discipline.	-Major concepts and their placement -Accuracy and uptodateness of content
–Stronger the discipline the greater is the		-Syntactical structure of the discipline.	-Index of pupil involvement

possibility of its reliable evaluation.			Development of scientific attitudes

5.3 METHOD

-Pupils learn better if meaningful learning experiences appropriate to their maturity level and experiential background are provided to attain the predetermined goals.	-Effectiveness of teaching learning strategies should be judged in terms of instructional objectives and students antecedents	-Entry behaviour -Teaching learning activities -learning out-comes -Feed-back mechanism.	-Pupils' initial learning. -Class room observation -Pupils' performance -Student reaction.

5.4 EVALUATION

5 4 1 DATA COLLECTION

-The more comprehensive data we have from different sources by differ-	-For collecting dependable evidence from different sources by the curriculum deve-	-Data sources -Data collecting devices -Nature of evidence acc-	-Opinion of developers and students -Tests, questionnaires.

rent people at different stages of curriculum development the more [illegible] and [illegible] judgements we are likely to make	lopers, different tools and [illegible] techniques should be used.	appraisal [illegible] [illegible] [illegible] [illegible] [illegible] students [illegible] [illegible] measures [illegible] [illegible] [illegible] -Relevance of tools -[illegible] -[illegible]

9.4.3 ANALYSIS AND INTERPRETATION OF DATA

-From output data [illegible] to [illegible] the basis of [illegible] [illegible] [illegible]	-Educational [illegible] to [illegible] [illegible] interpretation [illegible] subjectively accurate [illegible] [illegible]	-Criterion [illegible] [illegible] [illegible]

			ual outcomes. -Acceptable level of subjectivity.

6 4.3 MAKING JUDGEMETS

-The more explicit and precise is the statement of the philosophy of the curriculum project the more valid judgements are likely to be made.	-Depending on the purpose of the project, effectiveness of a curriculum can be judged in terms of absolute standards (goals) or relative standards of parallel or alternative curricula.	-Desired entry behaviour (DEB) and observed entry behaviour(OEB)of pupils	-Correlation between DEB and OEB DLX and OLX DLO and OLO
		-Desired learning experiences (DLX) and observed learning experiences (OLX) of pupils	-Relevance between (logical) DEB and DLX DLX and DLO
		-Desired learning outco-	-Relevance between

mes (DLO) and observed learning outcomes (OLO) of pupils.	(Empirical) OEB and OLX OLX AND OLO
-Desired (Absolute standards (DS) OR -Relative standard (RS) of another Curriculum with which to compare. -Accomplished standard (AS) of the curriculum under evaluation	-Extent of gap (Achievement) between DS and AS OR RS and AS.

7.0 THESES PROPOSED

On the basis of analysis made of the different curriculum components following theses are proposed for guidance of the curriculum developer teacher.

7.1 Since evaluation is the service component of every curriculum model, a theoretical framework of curriculum evaluation should be designed at the planning stage of the project so that role of evaluation at various stages of curriculum development may be appreciated by those who are involved in its development.

7.2 Formulation of curriculum objectives is a prerequisite to any systematic development and evaluation of a curriculum project. Such objectives should however, be treated as hypotheses, subject to modifications and revision, on the basis of empirical evidence, leading finally to emergent objectives against which summative evaluation may be done.

7.3 Since every discipline has its own structure, evaluation of curriculum content in a project must be geared to the substantive as well as syntactical structure of the subject.

7.4 Effectiveness of instructional strategy in a curriculum development programme should be judged in terms of learning outcomes and entry behaviours of students.

7.5 Since judgement making depends on the nature and quality of data every effort should be made to explore all the data sources and apply the relevant data collecting devices to procure the valid and reliable evidence about curriculum effectiveness.

7.6 Since educational relevance is of primary importance as compared to the reliability of measures, curriculum data may be analysed with reference to the criterion and not in terms of norms. As such criteria of a successful curriculum must be determined beforehand in order to interpret the data accordingly. Nevertheless, limitations of the data and subjectivity in interpretation have to be accepted as inherent weakness in curriculum evaluation

7.7 A good judgement can be made on the basis of clearly visualised desired standards of excellence and objectivity of adequate evidence Since strategy of curriculum evaluation rests mainly on the people and not on tools and techniques they use the evidence that we get is mostly based on pooled opinion and experience of those involved Therefore, methodology of processing judgement should mainly evolve from rational and illuminative evaluation of achievement of standards laid for a particular project Judgement with respect to comparative curricula should be restricted to those areas of achievement that involve the same basic assumptions from which common criteria of evaluation can be derived

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Part III Piagetian Thinking and Science Education

6

Research on Piagetian Thinking in Science

R. P. SINGH

It was asserted by Bruner (1962) that any subject could be taught effectively and in an intellectually honest form to any child, regardless of his age of development. This statement led to a loud controversy. Some used this idea to justify the presentation of molecular theory at primary level. Others believed that there was little to be gained by spending hours and days in teaching particular concepts to children when these same ideas could be learned in a fraction of time when the children were older. Finally, still others clearly disagreed with the statement by claiming that it was impossible for youngesters to learn certain concepts at an early age simply because their logical capacity was not developed.

In resolving this controversy much depends upon how we define the terms in original statement. That is meant by 'subject', 'taught', 'effectively' and 'intellectually honest form' ? The need for a completely planned experiment is thus evident. Perhaps in practice we will be convinced that additional emphasis in elementary school science should be placed upon the development of logical thinking as an effective means to increase learning. Perhaps still sooner we will find that the process of scientific enquiry should be more closely related to specific intellectual development. Since the intellectual development of the child is basic to the entire teaching enterprise, and since much attention is being paid to these matters in contemporary educational research, it is of considerable value for us to be aware of what is currently being discussed. We shall consider the question : Do children pass through specific stages of intellectual growth ?

We cannot discuss intellectual developmental stages without examining some of the original works carried on at the International Centre of Genetic Epistemology, Geneva, by Jean Piaget. Piaget's most notable and significant contribution to educational thought and practice has been his characterisation of specific developmental stages of children. The theory of Piaget has been well received by many educators and psychologists. A number of them have sought to utilize the theories in making adequate provision for his suggested stage differences in elementary school science. But what are the specific characteristics of the proposed intellectual stages, and how can we use this information in classroom ? are the questions which must be answered. In answer the following summary may be presented :

The Sensory-motor Stage : In this stage which extends from birth to 18 months (approx.) the child encounters objects by moving and touching without prior thought. Teacher is not directly involved with children in this stage, but psychologists believe that many fundamental foundational learning experiences occur during this period

The Pre-operational Stage The stage covers the period of 18 months to 7-8 years. The child during this stage is perceptually oriented. He commonly lives in an 'Alice in Wonderland' world when apparent visual contradictions do not cause any conflicts in his thinking. This is best illustrated by Piaget's famous experiment where two identical glasses, each containing the same amount of juice, are placed in front of a five year old child When the liquid from one of the glasses is emptied into a taller but narroewr glass, the pre-operational child will indicate that the latter now contains 'more' juice. Since he can focus his attention upon the change in liquid's height but he can not simultaneously consider the compensation by the difference in glass diameter, it is clear that the pre-operational child has difficulty in co-ordinating such variables. It is also clear from this experiment that the child in the pre-operational stage has not yet developed the concept of conservation. The pre-operational stage is obviously the time of free play and investigation. It is important, therefore, that teachers of primary classes provide opportunities for the children to engage in play of perceptive nature, using all of their sources to explain and observe the physical world It must be noted that the contact should certainly be conducted at the expense of forced and prematured verbalisation In science for children more emphasis should be placed on touch, taste, smell, listen, and watch.

The Stage of Concrete Operations : This covers the period from 7-8 years to 11-12 years The child is able to perform elementary logical operations Among the most significant development in this stage is the concept of conservations. The research conducted by Piaget indicates that the various "conservations" arise in the following sequence —

1. Conservation of number (6-7 years of age)
2. Conservation of substance (7-8 years of age)
3. Conservation of length (7-8 years of age)
4. Conservation of area (8-9 years of age)
5. Conservation of weight (9-10 years of age)
6. Conservation of volume (14-15 years of age)

Piaget's descriptions of the ways in which children respond to problems involving concepts of conservations have verified generally and have been found to be essentially correct.

The Propositional Stage —The period is 11-12 years and continuing through life. During this period the child has developed the capacity to engage in propositional logic. He is able to manipulate objects. He is capable of thinking systematically and in purely abstract terms.

The stage characteristics of all the stages are of importance for science educators. Some additional research work on problems of intellectual maturation is needed. This will have to be directed towards specific activities that embody recognised concepts and skills if we are ever to reach conclusions regarding the ultimate validity of utilizing Piaget's characterization of growth stages as a basis for establishing science curriculum sequence.

Kephart (1960) has concluded, as had Piaget before him, that normal sensorimotor development is a pre-requisite to orderly symbolic functioning. He along with his co-workers has developed a number of techniques for dealing with sensorimotor deficiencies.

Sigel, Roeper and Hooper (1966) conducted a study on conservation. In his study treatment and control groups, each consisting of five children, are matched on I Q, chronological age, social status, and educational level They predict that conservation will occur spontaneously if the child can master the operations of (i) multiple classification, (ii) multiple relationality, and (iii) reversibility

At the heart of Piaget's theory, as it pertains to how learning takes place, is the concept of mental equilibrium. In other words the thought process approaches a type of equilibrium as learning occurs. This is explained through Piaget's 'assimilation accommodation model" As new information is encountered, something jars the learner so that a temporary "disequilibrium" condition is set up As this new information is assimilated and the cognitive structure is accomodated to it equilibrium is restored once more Quite obviously then disequilibrium is an essential condition to learning In leading toward mental equilibrium we must be mindful of the importance of having the students engaged in thinking, in hypothesing, and in investigating, for this is the only way in which cognitive structures are changed In addition, the sequence in which we present learning stimuli is of singular importance Ausubel (1960) has examined this aspect and found that the cognitive structure is organised by highly generalised concepts under which additonal concepts and other information of a more specific nature are subsumed In this subsumption "theory of learning" the acquisition of new material is facilitated by the student's previous possession of introductory material that is more general, abstract and inclusive than the information it introduces These concepts are, therefore, considered to be advanced organisors, since they form a type of super structure under which subsequent learnings are categorised. Ausubel has indentified two types of advanced organisors Expository organisors are those that introduce materials that are totally unfamiliar to the student whereas comparative organisors are those that introduce information that related to previously learned materials. The presentation of either type of organisors must of course be made in terms that are familiar to the learner At the same time individuals must be aided in passing progressively from concrete thinking to more abstract modes of thought

Pinard and Laurendeau (1964) in an effort to extend Piaget's observations to populations other than that of Geneva, under conditions imposed by canons of experimental method, wanted to know whether Piaget's stages would survive that kind of scrutiny An intelligence scale was developed as a by-product. It may be pointed out that for the teacher who wishes to implement Piagetian ideas, it is, essential to ascertain the developmental level of the students being taught Reserches should be conducted to develop Piaget-inspired scale af intelligence and also for the psychometrization of Piaget's tasks,

There appears to be three principal ways in which Piaget's system could be applied to educational problems, Firstly, it may be possible to make fruitful use of Piaget's research instruments in the assessment of the individual child's general intellectual development Second, application involves the planning of curriculum in the context of Piaget's developmental findings As Flavell (1968) points out that this could take two forms First there is the question of grade placement of the instructional content. Do Piaget's findings imply, for example, that initial teaching of scientific method and content should be pegged around early adolescence, when formal operations which make possible genuine scientific thought are said to be developed ? What about the age placement of such traditional subjects as geometry ? Would Piaget's evidence that many of the basic elements of Euclidian spatial representation and measurement enter the child's thought by age nine or ten imply that geometry and related topics might be taught earlier than they asually are taught ? The second variety of this application can be summed up as : how can we make use of Piaget's data on developmental sequence to anticipate and guard, subtle non obvious "misacquisitions" whice he has shown the child is likely to fall prey to in trying to master a new area ?

A vigorous movement started among educators and and educational psychologists of the western world in the fifties of the century to effect a liason between Piaget and Pedagogy, particularly in regard to curriculum. Lunzer (1960) reviewed all such works from British literature National Froebel Foundation (1955) published collection of papers on Piaget's number research and other contributions Churchil (1958 a) Lovell (1959) Peel (1959) reported experimentation on Piaget's findings with implication for educational practice in mind

The third important way in which Piget's system could be applied to education may be put like this His theory has a good deal to say about the nature of the cognizing organism and the process by which unknown externals become known internals. It might be that this part of his system could tell us something about the most favourable conditions for learning, and hence, the way in which we should go about teaching The first application describeda bove had to be with the diagnostic assessment of the individual student, the second concerned the structuring of curriculum content in terms of normative developmental time table and the third one involved the methods by which the child ought to be taught, once curriculum content has been selected This can be divided into two components One consists of the specific problem of how by what inner process and in the presence of what external environmental conditions-the child typically acquires the various knowledge forms, that Piaget's research has shown and related to this, the potential implications of Piaget's theory. The other component has to do more with concrete and specific recommendations for actual classroom teaching, and for instructional method in content areas which Piaget has not studied experimentally

Piaget's researches on number and quantity have been popular targets for validation study during the past several years, probably because of their obvious implications in science education Dodwell (1960, 1961) gave a battery of Piaget's number tasks, using both individual (1960) and group (1961) administration, to large samples of kindergarten first grade and, second grade Canadian children. He found Piaget's all three stages in the development of number conservation. He also found that some of the number tasks showed more difficult developmental trends than others for the age range studied. It was also found that the various number tasks were of unequal difficulty with the consequece that a child who gave concrete operational responses to one problem might well give pre-operational responses to another Mannix in Lunzer (1960) found the following ordered sequence, first, mastery of conservation in the case of provoked correspondence, than in the case of continuous quantity, and still later, grasp of additive *composition* of *numbers*. Mannix also concluded, as did Dodwell, that Piaget was generally correct in his discription of the major types of responses children give to his number tasks Wohlwill (1960) also showed that the application of scaling techniques in this area could be a fruitful undertaking His datas indicated three major stages in the evolution of number concepts (i) a wholly perceptual approach (ii) a conceptual approach to individual Numbers, and (iii) a conceptualisation of the relationship among individual numbers Several other investigators namely, Churchill (1958 a, 1958 b), Harker (1960), and Wohlwill and Lowe (1962) have validated Piaget's analysis of number in broad outline

Piaget's work on the development of quantity concepts has also had its share of validation studies in recent years. Elkind (1961a) administered tests of conservation of number. His findings were (i) all three types of conservations are age dependent within this age range, (ii) conservation of continuous quantity is more difficult, (iii) correlation between conservation scores and subtest scores on the Weschler Intelligence scale for children were "generally positive, sometimes significant, and usually low". In another experiment Elkind (1961b) administered Piaget's tests for conservation of global quantity, weight and volume. Each type of conservation was found to be age-dependent. Lovell and Ogivie (1960) found Piaget's conclusions invariant. Some relevant researches have been reported in the areas of spatial concepts and time concepts

It has been my intention to point out some of the studies conducted on Piaget's thinking relevent to science education Unfortunately, a negligible effort has been made in this country to introduce Piaget in education and science education in particular.

Something must be told at this point regarding psychometric thinking on Piaget's thinking. The teacher without the knowledge of theory is likely to overlook gaps in the children's conceptual levels In order to make the teaching effective he should use tests before a new concept is used in the classroom Attempts have, therefore, been made in foreign countries to measure the conceptual attainments of children in various age groups Lovell et al (1969) by using the experiments of the type described by Piaget and Inhelder have desined tests to examine the ability to classify. Smedslund (1964) has performed measurements to determine the interrelations of various aspects of concrete reasonong as measured by a battery of Piagetian tests. Vernon (965) compared patterns of test scores with assessment of environment in English and West Indian cultural groups with a view to throw light on the development, and retardation in abilities. Kofsky (1966) has conducted a scalogram study of classification of development to two aspects of Piaget's theory. Bruner and Kenny (1966) has investigated how the child learns to grasp 'double classification that is classification of objects according to two of their attributes at the same time Beard (1963) has investigated the order of development of certain concepts in junior school children Beard hypothesises that the quantity-weight-volume order found by Piaget seems unlikely if experience rather than maturation determines the order of attainment of these concepts The order of attainment of number concepts, however, is likely to be vary less because of logical dependence of such concepts on preceding concepts Wallach at al (1967) studied to find whether conservation of number would be brought by training in reversibility alone or in addition and substraction alone. It was also examined whether the induced number conservations are transferred to other conservations. Lovell and Ogilvie (1960) traced the development of the concept of invariance to establish the arguments used by children to justify their answers Elkind (1961) did a systematic replication of Piaget's investigation of ages at which children discover conceps of quantity, weight and volume Gruen (1965) attempted to compare the relative effectiveness of two procedures for training children to conserve number Uzgiris (1964) investigated systematically the effect of varying materials used to test the conservation of quantity, weight and volume on the observed order of attainment of these concepts

In summary, Piagetian tests are relatively simple and some of them have direct relevance to the classroom. Nothing more need to be said here, beyond simply pointing out that for the teacher who wishes to implement Piagetian ideas, it is essential to ascertain the developmental levels of students being taught. There is, therefore, need of organising research on psychometric aspects of Piagetian thinking

Piaget is not in favour of literacy of habits He is dead against traditional method of rote learning and examination system He considers understanding subordinate to invention and rejects the method of force feeding information In Piaget's scheme of things adaptation to physical and social environment has been emphasised Adaptation requires assimilation and accommodation and hence the child is required to be inspired into learning process through his spontaneous activity Materials and methods have to be developed and teachers have to be oriented on these lines A coordinated research programme is needed to develop curriculum and testing materials on Piaget's lines.

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Part III Piagetian Thinking and Science Education

7

The Problematic Territory of Jean Piaget and Adolescent Thought

N. VAIDYA

Introduction

Man is an inseparable part of the evolution of civilization or humanity. Being human himself, what concerns children, teachers, teacher educators and researchers is of great concern to him for he himself has been a ceaseless inquirer into scientific, technical, social studies, and similar multifarious affairs. These reflections over the years have not developed in vacuum for educational ideas like scientific ideas have their remote past in educational principles rooted in the wisdom of the ages traced back to the ancient Greek thinkers like Socrates and Plato. Since then the ideas of many great thinkers representing different disciplines have been woven into the fabric of current educational philosophy and practice, When given this environment, Jean Piaget drinks heavily from this philosophical spring. While doing so, he appears to pay back his ancestral debt abundantly in his own life time to the moderns as well as the futurists for a is impossible to imagine today cognitive study without reference to his work. Whether one agrees or not, a dip in the 'Ganges' of Piaget, does affect one's outlook on problems educational. Why ? Because he presents some sort of thought provoking synthesis as obtaining in rationalist tradition of Plato, mental categories of Kant, notion of perceptual change as propounded by Bergson, productive thought of Gestalt psychologists like Max Wertheimer and use of logic for interpretation of thinking (classes, relations, grouping, reversibility and equilibrium) coupled with the cumulative influence of several individual personalities like Calvin, Rousseau, Pastalozzi, Claparede, Binswanger, Bleuler, Rorschach, Meili, Jung and Sechehaye (4). Philosophical problems continue to recur century after century for philosophers perhaps in the true tradition of their own beloved subject pose their problems in unsolvable forms (3). Piaget, while still remaining a firm speculator, succeeded in stealing part of this territory by tackling psychologically an age old epistemological problem as enunciated by Plato "How and when can man be sure that his knowledge is true knowledge, when time and again he finds that what he took to be knowledge has proved to be error" (1). In this act, he not only kicked aside the fairly well established scientific procedures by establishing his own METHODE CLINIQUE but also constructed his own symbolic logic for interpreting intellectual operations as they develop from the very early childhood to late adolescence. He thus showed how child, nay a universal child, goes about the business of constructing his own house of knowledge. Continuously bitten by this problem over a period of forty years, he came up with this grand hypothesis .

Development is continuous not only within the individual but throughout all evolutionary levels. From the biological to the social to the intellectual levels, the unity of nature is preserved. The functioning of the lowliest mollusk is based upon the same fundamental processes as that of Einstein.

The Nature of the Problem

Thinking is a 'ghost' - like activity for it has to be inferred rather than observed. In literature, it has been referred to as 'abstracting, analysing, comparing, deducing, defining, discriminating, estimating, generalising, guessing, imagining, judging, knowing, opining, reasoning, recalling, recognizing, reflecting, remembering, searching for conclusions and understanding. While going ahead, one visits the territory of concept formation, it again turns out to be a vast area of investigation in its own right having strong links but, at the same time, not identical with such complex psychological processes as thinking, learning, problem solving, language acquisition and symbolic representation. If this journey is further continued, one enters the complex areas of problem solving, creativity, critical thinking and originality where one is caught into several definitional difficulties. One is very lucky, if not lost, for every milligram of information obtained there is a quintal of effort to expend. And here the distinction between original sense and original non-sense disappears. Not long ago, the nuclear scientist Oppenheimer aptly remarked, "It is the business of science to go wrong". Difficulties therefore, for the cognitive psychologist multiply several folds and for achieving success, problems have to be posed more and more productively in the phraseology of Gestalt psychology with a view to investigate the highly varied complex processes of thinking which may ultimately lead to the development of understanding, generalization, discrimination, concept development and attainment The problems do not end here because the researchers and the practitioners do not invariably ask the same question These split questions and possibly the consequent split answers are bound to appear in the business of any science, educational psychology, being no exception The workable solution under these circumstances lies in considering the two in isolations as is frequently done while managing anamolies in science. The basic problem here is to relate the most powerful concepts of science to the mental development of childern whose answer goes a long way in providing the psychological structure to any one of the school subjects Thanks to the recent efforts of Ausubel, Bartlett, Beard Bruner, Flavell, Gagne, Guilford, Hans Furth, Hearnshaw Humphrey, Inhelder, Lovell, Lunzer, Peel, Kraplus, Piaget, Schwab Skinner, Suchman, Vernon and Wallace, the problem territory in this decade has been exploded and consequently, the problems in pieces, like the discovery of fundamental particles in atomic physics, lie more in the zoo rather than in the jungle. This was hardly the case over twenty five years ago The emerging literature on thinking clearly tells that children learn spontaneously, they acquire schemes of thought regardless of school influences They learn from each other, and learn equally well in formal situations At the same time, they also possess first hand knowledge about men, and their affairs in their immediate environment This does not amount to saying, the Sun rises in the East or sets in the West It, on the other hand, means that the child's thinking is not at all a chance or random behaviour. It is sensible, intelligible and predictable against the available theoretical psychological constructs (3).

PROBLEMS POSED IN THE FIELD.

In this perspective, the field as a whole poses the following problems which overlap each other to a varying extent:

(1) What are, specifically speaking, those conditions under which learning takes place maximally ? What exactly is the role of hints and cues either in supporting thinking or in the formation of concepts ? To what extent can concepts be down grades ?

(2) At what age is formal reasoning manifested among different categories of pupils ? How is formal reasoning different from concrete reasoning ? What conditions determine transition between the two stages ?

(3) How is thinking generalized in each of the two grades ? Does it develop in stages ? Is it possible to accelerate stages ? What is the role of planned experiences in concept development and problem solving ? Is creative thinking also influenced as well ?

(4) Does 'instruction precede development' (L S Vygotsky)? Is learning to take place mechanically or from page to page within the textbook ? Or is it possible to save children from subsequent teaching once the initial learning has been fully acquired ? Quoting J S. Bruner "Is it possible to get a maximum of travel of what we have learnt ?" If so, what kinds of thinking processes does training generate under different conditions ? Are they chips of the same block or are they different , Are they of temporary or of permanent character ?

(5) What errors children exhibit at various age levels? Are they, psychologically speaking, interpretable? Is it possible to develop a museum of these errors? Is it possible to demolish this museum through intervention? What about the role of maturity here?

(6) Is learning possible in the absence of schemes of thought in relation to academic subjects taught at school? Do these schemes of thought have any psychological existence or relevance?

(7) Why children fail to verbalize their concepts or methods of procedures especially when they have, in fact, acquired them?

(8) Lastly and basically, how children coordinate information? What are the underlying mechanism? Have they strong links with symbolic logic? Are they of any psychological significance

Analysis of Adolescent Thought

The writer investigated adolescent thought with the help of specially designed problem (N — 17), each inhering a continuous chain of reasoning (5). This study, using case study approach, also attempted to delineate the structure of the various hypothesized schemes of thought factorially In this field experiment, 200 pupils (100 boys and an equal number of girls) studying in grades VI through X, matched on intelligence and socioeconomic status were observed, solving a series of seventeen different problems in two sessions. The main findings of this study indicated .

(1) Except occasional fluctuations, average performance on each problem increases with grade Mean performance in most of the cases favours boys rather than girls. But both boys and girls try hard to equalize their performance as they move in to higher grades.

(2) A given problem, part of the problem or a process in that problem is solved successfully (or failed) over a wide I. Q. range both within and across the various grades.

(3) A given problem is solved in stages. It is possible to identify stages in the solution of any problem.

(4) Unexpectedly, pupils commit a large number of errors while engaged in problem-solving. These errors further increase in the higher age groups when they fail to grasp the main requirement of the problem. Among these errors, the dominant ones, shared by more than 15 per cent of the pupils, largely speaking suffer a hump before they finally decline with increasing grade.

(5) Contrary to Piaget, pupils are not in a position to exhaust or suggest all possibilities, combinations and tests. Over three-fifths of the pupils from grades VI to VIII are badly affected when a problem inheres reversibility in thinking.

(6) The complex problem solving processes arise from simple thinking processes.

(7) The role of the nature of the problem being critical in investigating thinking, adolescent pupils, contrary to Piaget, are affected to a great extent by the content of the problem.

(8) Whereas adolescent pupils are in a position to set up hypotheses, they are not in a position, contrary to Piaget, to test them which shows that their minds have not yet become experimental. Most of the adolescent pupils do not, contrary to Piaget, process schemes of proportion as well as generalization to algebraic symbols.

(9) When a problem is solvable through two schemes of thought, one inferior and the other superior, and if the latter is not well developed, the resort to the former may favour quite a few in solving that problem. In case both are conspicuous by their absence, there is little chance for the supplied hint or illustration or even analogy to be utilized in solving the problem successfully.

(10) Except occasional fluctuations, the mean performance on the various schemes of thought shows an increasing trend with grade. When mean and standard deviation are kept at 20 and 3 respectively, the gains interms of T scores over the five years period are dismal implying thereby that they are characterized by gradualness, slowness and laboriousness as they evolve across the grades.

(11) Using Principal Component Analysis on the combined matrix, containing forty five variables and the varimax rotated factor structures with a view to obtain the hypothesized factors and interpret them psychologically, the following multiple factors appeared :

(i) Schematic Learning General
(ii) Adjustment
(iii) Problem Orientation
(iv) Sensing Problems
(v) Symbolization
(vi) Testing Hypotheses
(vii) Using Constant Difference
(viii) Aspect Character
(ix) Seeing the Problem as a whole.

(12) The top group differed from the bottom group on all the five measures of adjustment, understanding of the problem and all the seventeen schemes of thought. They, on the other hand, did not differ significantly from each other in respect of the following variables , felt difficulty of the problem, confidence in the problem and interest in the problem.

At this stage, it is necessary to highlight an interesting finding, hardly looked for, in this investigation. It has appeared in several contexts : supplying an answer already available within the body of the problem, last item needing an arithmetical or algebraic anwer, counting the total number of traits or efforts made ; returning to the same step after suggesting other steps ; and the number of arbitarary and extraneous considerations brought into the problematic situation during problem solving Why should these errors suffer hump in the face of increasing understanding with age ? Is it the case of lack of seriousness on the part of the adolescent ? Is it the case of the adolescent standing on the hours of a dilemma and getting murk ? Is it the case of the adolescent trying hard to close in on the problem solwing process through steps totally irrelevant to the solution of the problem ? Does it exemplify, suggesting in the process that mastery over a thought process is through a path . hardy, thorny and erratic ? It is the case that the adolescent regresses as if on a pleasant and adventurous Piagetian Journey during which, while unaware of the logic he is using, he is trying hard to educate out himself as if the right path to concept development lies in flourshing an experimental failures Or alternatively, is it a case of rubbing his schemes of thought wrongly especially when he has personal reservations about his self acquired knowledge in contrast to school learning which does not set right his firmly held selfcentred thoughts ? It appears to be anybody's guess. In a personal communication, J. S. Bruner, who had encountered this phenomenon earlier and had not followed it up, had this much to say .

The type of error that you refer to, which we speak of growth error, is one in which the growing child tries out a new strategy although it is not well developed and uses it in place of an older one which has been working well. It is errors of this sort which suggest to me, the venturesomeness of learning during this early period that human beings are willing to shift to a less certain more powerful strategy before they have it under control in preference to one which is safe, sound and dull

Any way, only a longitudinal study is going to establish this Brunerian hypothesis. Returning to the Hump effect, in Serial rote learning, Hump effect in the form of 'bow' has appeared when frequencies of errors were plotted for a group of subjects engaged in learning each item in the Serial Position Effect. In the context of this study, the problem arises : Does Hump effect exist at the lower stages of mental development as well ? If so (and cofirmed), a short tunnel to learning may be obtained which may be theorized upon like the theory of fermentation. If effort in this direction is successful, the needed fill up may usher in the second psychological revolution in learing consistent with the spirit of educational technology especially when the second scientific and industrial revolution is picking up very fast in our country.

The investigation of human thought processes in all their varied aspects is a complex task, so both problems nap acts of problem solving are bound to appear refractory both to the psychologists and the method specialists Their troubles are bound to increase still further even when there is no unanimity in reported literature on the very difinitions of thinking, concept formation and problem solving. Also how an experimental situation is to be finally selected and approached for the very literature in this area is little organized. But these difficulties, present to a varying extent in any business of research need not deter the future investigator on thinking. Over two thousand years ago, Plato talked of breaking the problem at its joints. The opportunity for that has just arrived as aptly put forward by Hyde.

There is scope for all, the clinician can study the abnormal functioning of the structure, the educationist, the effects of training on its growth, the sociologist, the effects of environment and others, modifications due to individual differences The body of knowledge about children that may eventually result from his work, directly or indirectly is incalculable (6).

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Part iii Piagetian Thinking and Science Education

8

Implications of Piagetian Research for Science Curriculum Development

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Research in science education suffers from conceptual sterility and therefore ends in triviality (Cooley, 1961; Novak, 1974, Raths, 1973, Tyler, 1967; Volker and Wall 1973; Watson, 1963) However, in recent years there has been an awareness as to the need for conceptually-based research in science education. Piagetian system offers such an alternative.

Piaget is an empirical genetic-epistemologist. He is not interested whether the world is real but had studied changing cognitive structures by which the growing child copes with the world. Hence, his primary interest lies in how children develop cognitive structures from birth to adolescence.

Dyril (1970) from writings of Jean Piaget has interpreted characteristics of Concrete and Formal stages as follows :

Concrete Operations (7-8 years to 11-12 years).

(a) Thinking is concrete rather than abstract, but the child can perform elementary logical operations and make elementary groupings of classes and relations (e. g., serial ordering).

(b) The Concepts of conservation develop (first of number, then of substance, of length, of weight and finally of Volume).

(c) The concept of reversibility develops.

(d) The child is unable to isolate variables, and proceeds from step to step in thinking without relating each link to all others.

Validation of development within concrete operational period has been more thorough and systematic. Many studies (Bat-Haee, 1971, 1971a; Carpenter, 1955, De Lemos, 1966, Dowell, 1960, 1961, 1962, Elkind, 1961a, b, c, d, 1962, Goldschmid et. al., 1973, Hood, 1962; Hyde, 1970; Kooistra, 1973, Lourendeau and Pinard, 1962; Lloyd, 1971; Lovell and Ogilvie, 1960, 1961a, b, Lovell and Slater, 1960, Lovell, Healey and Rowland, 1962; Lovell, Kellett and Moorhouse, 1962, Lovell, Mitchell and Everrett, 1962; McRay 1971; Pachauiy, 1974, Uzgiris, 1964; Vernon, 1966, Za'rour, 1971a, b) lend strong support to the majority features of Piaget's system namely, (a) that quantitatively different modes of response are associated with different age levels to the extent that it is reasonable to talk of concrete operational thinking, (b) that development on the developmental tasks is related to age, so that one can talk of a general sequence of development; (c) that the ages stated by Piaget for the various achievements are by and large, representative. These conclusions apply to different conservations of quantity (Bat-Haee, 1971, 1971a; Elkind, 1961a; Lovell, 1959; Pachaury, 1974, 76), weight (Bat-Haee, 1971, 1971a, Elkind, 1961b; Lovell and Ogilvia, 1961a; Pachaury, 1974, 1976), Pachaury 1974, 1976), and other concepts such as number (Beard, 1963; Dodwell, 1960, 1961, Elkind, 1964, Hood, 1962; Lloyd, 1971; Rothenberg and Courtney, 1969; Rothernberg and Orost, 1969) and classification (Elkind, 1961; Kofsky, 1973, 1966; Hooper et. al., 1974; Pandey, 1975). Estes (1956) found nothing to support Piaget and Hyde (1959) found reversal in horizontal decalage and no evidence of appearance of stages. A negative note comes also from Peking, China (Cheng and Lee, (1960), where the results of "an experiment" are said to run contrary to the contention of the "bourgeois scholar Piaget" that children's conception of number is completely determind by age. Other studies refute this (Board, 1961; Dodwell, 1960, 1962; Elkind, 1961a b, c; Feigenbaum, 1963, Hyde, 1959, Lovell and Ogilvie, 1961a Mannix, 1960; Noro 1961; Pachaury; 1974, 1976, Price-Williams, 1961; Robertson, and Richardson, 1975; Vzgiris 1964; Wohlwill, 1960, Woodland, 1961). However, it is interesting enough that there is some consistency in that some conservation skills may be necessarily universal (Goodnow, 1962; Greenfield, 1966; Hyde, 1959; Lloyd, 1971; Peluffo, 1967; Prisce Williams 1961, 1962).

Formal Operations (11-12 years to 14-15 years).

(a) Stage of formal (abstract) thought marked by the appearance of hypothetico-deductive reasoning based upon the logic of all possible combinations, the development of a combinational system and unification of operations into a structured whole.

(b) The development of the ability to perform controlled experimentation, setting all factors "equal" but one variable (at 11-12 years to 14-15 years, the child's formal logic is superior to his experimental capacity). Individuals discover that a particular factor can be eliminated to analyze its role, or the roles of associated factors

(c) Reversal of direction between reality and possibility (Variables are hypothesized before experimentation).

(d) Individuals discover that factors can be separated by neutralization as well as by exclusion.

Dale and others (Elkind, 1961; McKinnon, 1970; Renner et. al., 1973) found that formal thinking develops much later in adolescents. Studies of Ball (1972); Case and Collinson (1962), Lawson (1974); Lovell (1971); Randall (1967) indicate that many adolescents are somewhere in a transitional state between concrete and formal operational stages On schema of proportion only 50% of the 15-year old showed formal thinking (Lovell and Butterworth, 1966). Formal thinking in history comes about 16 to 16.6 years of age (Lovell 1971). Shifts in thought processes may occur at different times in different subject matter areas. Thus, an individual may have reached the formal stage in science while not demonstrating formal thought in social studies until several years later (Stone and Ausubel, 1967) Lovell (1961) found that 10 Teacher's Training College Students barely reached formal level of thinking. Elkind's (1962) subjects who were college students 42% gave erring explanation of abstract concept of volume as given by children except that their language was more sophisticated. Almost similar findings are reported by others (Chiapetta, 1974, Chiapetta and Whitefield 1974, Friot, 1970, Higgins-Trank and Gaite, 1971, Howe, 1974, Juraschek, 1974, Karplus and Karplus, 1970, Karplus and Peterson, 1970, Keasey, 1970; Kohlberg and Gilligan(1971)Lawson, 1974, Lawson and Black, 1976, Lawson, and Renner, 1975,-Mckinnon, 1970; Mckinnon & Renner, 1971, Norland et al. 1974, Pachaury, 1974, 1975, 1976, Renner and Stafford, 1973, Sayre and Ball, 1975, Schwebel, 1975, Towler and Wheatley, 1971, Wollman et. al. 1976). In a study by Wason (1968) where the subjects were required to isolate variables and subject them to a combinatorial analysis, 60 to 75% could not solve this problem. This was formally replicated by Dawes (1971) with subjects who had Ph. D 's in mathematical psychology Only one of five subjects correctly solved the task ("...........I feel constrained not to reveal the names of these mathematical psychologists, but they are all well published at least in my biased estimation highly regarded members of their fields"- --Dawes)

TRAINING STUDIES :

Results indicated that the Piagetian concept of conservation was not induced by any of the training techniques regardless of the population (Almy et. al. 1966; Beattson, 1975; Beilin and Franklin, 1962, Bruner et. al. 1966, Gruen, 1965; Harker, 1960; Jacob and Vandeventer, 1968; Kingsley and Hall, 1967; Mermelstein and Schulman 1967. Mermelstein and Mayer 1969, Mermelstein et. al. 1967. Resnick et. al., 1971; Smedslund, 1961a, b, c, d, e, Smith 1968; Strauss and Langer, 1970, Wallash et. al., 1967, Wallach and Sprott, 1964, Winer, 1968, Wohlwill, 1960, Wohlwill and Lowe, 1962). On the other hand others utilizing a variety of techniques have induced different kinds of conservation (Coxford, 1964, Beilin, 1965, Brainerd 1972a, b, press; Brison, 1966; Brison and Sullivan, 1967; Bucher and Schneider, 1973; Bruner et. al., 1966; Feigenbaum and Sulkin 1964, Fournier, 1967; Gelman, 1967, Goldschmid, 1968a, Halford, 1968 Hamel and Riksen, 1973; Hatano and Ito, 1968, Hatano and Suga, 1969, Inagaki, 1970; Inagaki and Hatano 1968, 1972; Jacob and Vandeventer, 1969, Kohnstamm, 1968, Lasry, 1968, Lefrancois, 1968, Minichillo and Goodnow, 1969, Murray, 1968, Peilet et. al 1971, Peter, 1970; Roll 1970, Rothenberg and Orost, 1969, Siegel et al 1966; Shantz and Sigel, 1967, Smedslund, 1961a, b, c, d, e, Sullivan, 1967, 1969, Waghorn and Sullivan, 1970, Wohlwill, 1960; Wohlwill and Lowe 1962) Piaget maintains that three criteria deemed important in deciding whether an investigator has succeeded in teaching operational structures. They are :

1. Is the learning lasting ?

2. How much generalization is possible ?

3. In the case of each learning experience what was the operation level of the subject before the experience and what more complex structure has learning succeeded in achieving ?

Researches of Chiarotta (1973) Chiappetta and Collette (1975) Brison (1975), Brainerd and Allen (1971a), Caruss and Resnick (1971) Fournier (1967), Gelman (1967) Glaser and Resnick (1972), Goldschmid (1968a, 1971) Goldschmid and Bentler (1968a, b), Hamel and

Rickson (1973). Jacob and Vanderventer (1969) (moderate level transfer Lister (1969), Parker et al (1971) Schnell et al. (1972) meet the first two criteria fully well Acceleration of structured' ensemble seems doubtful by short training techniques in Piagetian system :

The on going process where by the individual gains knowledge about the external objects the self, and self object relationships is considered to be a natural outcome of an active interactionist system Epistemologically in a very real sense the individual constructs himself and the world around him. At no point in Piaget's model can man or the external world ever be defined independently of each other, the changing structure of each is muturally derived from this continuing dialectic (Riegel, 1973a, 1973b)

Delay either in the attainment of concrete operations or formal operations (also training effect) are attributable to poor reinforcement by syntactical structure on cognitive operations, and if children from different cultural and subcultural backgrounds experience different syntax then differences in competence for soulution of Piagetian type task may in part be explained by such differences in language environments (Barnes, 1962, Bernstein, 1960, 1961, 1962, 1964; Best 1964, Deutsch, 1963, 1964, 1965, Fischer, 1958, Hess and Shipman, 1965; Higgenbothem, 1961; Hoehstetler, 1961; Jensen, 1964; John and Gradstein. 1964; Loban, 1964; Noel, 1953; Passow, 1963, Sigel et al, 1966; Sigel and McBane, 1967, Thomas, 1962). Bruner (1961). supports this ' The disadvantaged child lacks both the richness of environment for developing models and strategies of thought and the corrective feedback necessary for their maintenance. Through models we consume information in the form of concepts and through strategies we learn to make inferences or go beyond the information given.

According to Reynell (1969) concept formation is contingent upon Input experiences of communication Sensory channels are perceptual process and to the extent stimulus-deprived child lacks these, his conceptualization is inadequate and faulty as evidenced by low SES children (Buell et al, 1970, Pachaury, 1974) Sachs (1971) suggests that "there is a complex interaction between conceptual development and language development" Conceptual development in science suffers from rhetoric of conclusions (Schwab). Understanding science means appreciating its modes of inquiry Therefore, teaching for conceptual development and the pupil attainment of concepts are interdependent processes. Hence, 'one-shottelling' is a very poor strategy for scientific conceptualzation.

Conceptual understanding is characterized by (Hurd, 1971) :

(a) distinguishing examplars from non-examplars.
(b) to interpret new situations using the concepts.
(c) to use the concept as a hypothesis.
(d) to make valid inferences or generalizations.
(e) to make predictions.

This is possible when science curriculum is built around major conceptual schemes, where a child gets an opportunity to interact with the environment in a multi-contextual and multi-media fashion and thus would be able to operate at the formal operations stage.

As reported by Lawson (1974a,) even American [illegible] with [illegible] are not concerned with [illegible] formal thinking in the pupils, but are [illegible] abstract concepts so much so that [illegible] of the pupils do not attain formal thinking by [illegible] these experiences (BSCS, PSSC, CBA, [illegible] (1966) results show [illegible] the new elementary pro- [illegible] AAAS, [illegible] Cleveland Mathematic [illegible] had any accelerating effect on the development of [illegible] operations. Findings of [illegible] and [illegible] (1968), [illegible] (1968) [illegible] and [illegible] support Almy's results. Therefore, it is evident, Indian [illegible] either adaptation or parallel [illegible] American counterparts. Conclusions of Lawson (1976), Almy (1966) and others [illegible] hold good for Indian curricula also. [illegible] problem of differential curricula rather than [illegible] for all. Secondly, [illegible] be taken as granted [illegible] follies already committed. Therefore, a research strategy based on empirical finding has to be adopted. A new curricula geared accordingly would then facilitate formal thinking in pupils. Thus a Piagetian theory-based curriculum and its evaluation seems very much warranted.

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Part III Piagetian Thinking in Science Education

9

Research on Piagetian Thinking : Some Efforts at Punjab University

I. N. JOSHI

The resurgence of interest in cognitive processes and cognitive development during the last three decades or so is reflected in the increased attention the developmental psychologists have given to the acquisition of cognitive skill in children. There is little doubt that a major source of impetus has been the works of Piaget and his colleagues related to identifying the developmental stages in the acquisition of concepts in subject areas such as Causality (1927), Judgement and Reasoning (1924), Moral and Judgement (1932), Thought and Language (1923), Movement and speed (1946), Logic (1959), Time (1946) etc. The emphasis on process involved in the acquisition of knowledge has resulted in a unique system defining the development of intellectual structures.

Most of Piaget's works have encouraged educators and psychologists to replicate his studies with more sophisticated controls Considerable interest has been shown by various researchers to investigate into the acquisition of mathematics and science concepts as related to the courses of studies in schools and contingent upon Piaget's formulations as to the stage of development of thinking processes

The research projects listed below were completed in the Department of Education, Punjab University during the year 1965 to date The main purpose of majority of these investigations was to relate development of Science or Mathematics concepts relevant to syllabuses with various stages of schooling

(1) Development of Algebric concepts in pupils in Relation to Intelligence, Sex and Grades at the Junior Secondary Level

(2) Mathematical competence of Prospective Elementary school Teachers

(3) Effect of Intelligence and Age on the Development of Numerical Ability in Children at the Junior Secondary Stage

(4) A study of basic concepts of geometry through tests to be constructed

(5) Modification and Standardization of Test of Basic Concepts of geometry.

(6) The Effect of Intelligence, Sex and Residential status on the understanding of Mathematical Concepts at the Junior Secondary stages.

(7) Understanding of concepts of Chemistry by the stude-

nts of IX Class in relation to their intelligence, sex and rural/Urban background.

(8) Understanding of fundamental concepts of Physics by the 10th class students in relation to their intelligence, sex and scholastic achievements.

(9) Piagetian Concept of Time and Motion, an empirical validation.

(10) A factor analytical study of problem solvihg ability in Algebra.

(11) Development of number concept among the children (age group 5-10 years) in English Medium school.

(12) An investigation into the patterns of thinking in solving problems in Algebra in relation to intelligence

10

Sociology of Science Education : Problems and Research Perspectives

SATYA PAL RUHELA

Sociology studies social institutions. Science is also a social institution in modern times, and so it also comes within the purview of sociology. In fact, so much interest has been generated in this direction that a very specialized field of study entitled 'Sociology of Science' has emerged during recent decades to study various aspects of the relationship between society and science. According to Joseph Ben-David the sociology of science studies the way in which scientific research and diffusion of scientific knowledge are influenced by social conditions, which, in turn, influence social behaviour.

Various sociologists like Robert Merton, Sorokin, Bernard Barber, Walter Hirsch, E. Hegal, B. Hessen, Joseph Ben-David, Randall Collins, S N Eisensteadt, etc have enriched this field with their contributions. *The Sociology of Science* edited by Bernard Barber and Walter Hirsch (1963) still remains a classic book of readings in this field, although newer contributions are being added to this field by sociologists and educationists of many countries

The growth of the field of sociology of education can be divided into two periods the first one starting from the early 1920s to the end of the 1930s, and the second one starting after the world War II and lasting to date.

During 1920-30, the major writing and research interests in this field were . role of science in social change, problem of resistance and suppression, social functions of science, conceptualization of the informal social system of science, and the social history of science and technology in the seventeenth century. The post War developments in this field have revealed these trends : interactional study of the scientific community, socialization of younger scientists, scientists' interest in philosophical ideas and theories conceptualization of scientific interaction, influence of class interests, racial origin, political ideology on science, social responsibility of the profession of scientists, institutions of scientific activity, science in totalitarian societies, and very few studies on the social effects of science.

Essentials of the sociology of Science

1. According to Talcott Parsons a sociologist, the basic norms of any scientific knowledge are ' empirical validity, logical clarity, logical consistency, and generality of the principles involved.

2. German sociologist Max Weber believed that the belief in the value of scientific truth is not derived from nature but it is a product of definite cultures

3. Robert Merton has demonstrated that there has always been existing a latent and active hostility towards science in many societies which hinders or slows down the pace of develoment of science in those societies

4 Scientific research is not conducted in social vacuum.

5 Most institutions demand unqualified faith, but the institution of science makes scepticism a virtue

6 Dictatorship organizes, centralizes and hence intensifies sources of revolt against science which in a liberal structure remains unorganized, diffuse and often latent

7. A scientist has to undergo special careeristic stresses His whole personality is so moulded by his profession that hard work, devotion to duty, fearlessness and sobriety become the very elements of his nature.

8. Any scientific achievement is the result of accumulated effort of many scientists. Newton's classic statement is worth remembering If I have seen farther, it is by standing on the shoulders of giants

9. No modern scientist believes that he will ever be able to make a grand invention by serendipity pattern, i.e by an accidental happening or by just a stroke of luck Systematic and strenuous research work done by him, taking help from is hpredecessors and contemporaries, only can produce outstanding inventions or findings

10. It is in the very ethics of the profession of scientific researchers to stand for truth discovered by them, and to be prepared to sacrifice even their lives for the sake of truth. The long social history of science is full of many

such inspiring sacrifices made by scientists of conscience and integrity. That nobel tradition continues in most of the countries even today. The respect of independent scientists and university scientists is definitely greater than bureaucratic scientists, working in governmental and semi-governmental agencies

11 According to Max Weber "in the field of science only he who is devoted solely to the work at hand has presonality." He further holds "only by strict specialization can the scientific worker become fully conscious, for once and perhaps never again in his life time, that he has achieved something that will endure."

12. The practice of affixing the name of the inventor or discoverer to all or part of what he has found, e.g. Copernician system, is only the most enduring and perhaps the most prestigious kind of recognition institutionalized in science. Anonymous or mediocre research assistants have no place in this scheme of things

13 According to Edward Shils, "the freedom of publication and discussion is absolutely central to the tradition of science."

14 Plagiarism and fraud are outside the culture of scientists. A scientist is morally bound to give due credit to other scholars from whose works he has benefited

15 The applicational aspects of science i.e. technologies of different kinds are of crucial social, cultural, political and economic importance since their basic purpose is to make man's life easy, comfortable and fruitful

16. Science as an agent of social and cultural change and modernization is very much recognized all over the world.

Sociology of Science Teaching in Schools

In most of our schools there are shortages of labs, tools, materials, dedicated, well trained and innovative teachers, and of the continuance of stale courses and anomie (normlessness) in the use of science teaching methods. We find many science teachers asking students to read out from science books in classes instead of getting the experiments (even those prescribed in the syllabus and described in the textbooks) actually done by them. The high expectations of our scientists, educationists and leaders usually remain unfulfilled because the science books are written either in difficult English or Sanskritized Hindi which is even more difficult for the students to understand. Many science teachers are frustrated, apathetic, unenthused, and tuition-hunters. They fail to cross the barrier between the cultures-the culture of science and that of humanities and social sciences. There are schools in which science kits, so enthusiastically sent by Unesco or NCERT, remain unopened and unused for years and they just lie in the dingy corners of school libraries

Science Education under the 10+2 Scheme

The new curriculum for Classes IX and X, developed by the Central Board of Secondary Education, New Delhi, has envisaged a comprehensive course of general education with provisions for work-experience. A minimum essential core of knowledge for promotion of intellectual capabilities has been provided by teaching subjects like languages, mathematics, sciences and social sciences. The terminal behaviour on the part of the students, in so far as science is concerned, is that the student will have a proper understanding of fundamental concepts of basic laws of nature and their operations, and also be able to have the knowledge of the methodology of applying such knowledge to the solving of everyday problems in a scientific manner

The curriculum-framers have prescribed several topics in three prominent sciences—physics, chemistry, and life sciences. It is for the subject teachers to tell us now as to how far are these courses suited to our social and cultural contexts Are they psychologically motivated to the students ? Are they full of potentialities for the welfare and enlightenment of our masses ? Are they too light or too heavy to discourage the students ? Are they really modern courses or just old wine in new bottles ? Is it possible to apply new science methods in teaching them ?

The author finds that the curriculum-planners have paid scanty attention to the socio-cultural context and the proper methodology of teaching science At Classes IX and X, the most useful methods would have been the biographical method the observation method, and the experimentation method. The life of a scientist, vividly presented, describing his background, frustration and achievements, etc should serve as the most effective medium for communicating knowledge, impressions and values of science. The importance of field-observation, nature study, project and experimentation cannot be overlooked

What types of teachers are needed for teaching science ? What personality patterns and competencies should they [illegible] ? [illegible] going to be grand preceptors teaching [illegible] without having proper qualifications, aptitude and competencies for them ?

Research Needs in Science Education.

The Regional College of Education, Ajmer, organised on 22-26 March 1976 a workshop on "Research in Science education" in which research needs in science and mathematics and sociology of science were discussed by the participants. The consensus of the workshop was that research in science education in our country is still very litte, almost primitive. There is no research work in the area of sociology of science education. There are no fundamental studies on the pattern of HPP (Harvard Project Physics). There are no studies available on the comparative advantages of new physics versus old physics. The Third Indian Year Book on Education (NCERT, 1968) and A Survey of Research in Education (1974), clearly shows that there is very little of research in India on the sociological aspects of science teaching, and whatever research is there on the teaching and curriculum of science in Indian schools is not creative and functional in the socio-cultural context.

It is necessary to think of evolving research topics in a sociological perspective. Factors like rural urban social groupings, religion, superstitions, traditions, economy, caste, social class, language, occupations, symbols, public cooperation, opposition, expectations, and needs of the rural masses, politics, bureaucracy, etc. should be closely studied in so far as they affect science education in today's schools. Their impact on TV, radio, journals science comics and fictions, exhibitions, science contests, etc also deserves to be studied

The socio cultural backgrounds career patterns, motivations, frustratation, training, reorientation of science teachers, and the effectiveness and utility of seminars, work-

[illegible] etc — all these are vital research priorities in science education. Research is urgently called for in the personality patterns of students who should take up higher science in their college career.

A lot of meaningful research is needed on textbooks, equipment, improvisation of tools and procedures, and the pupils' interests, achievements, and difficulties in science subjects being taught to them. How much of science knowledge has, in fact, gone into their daily habits and in the daily life of their relatives in their families as a result of classroom instruction, is yet to be investigated.

The cost-benefit analysis of science tools, methods, laboratories, and the value conflicts of students, teachers and parents are also significant topics for the researchers in science today.

The sum and substance is that we must let our science teachers, their training, their backgrounds, their teaching methods and strategies, science curricula, science books, science laboratories, science clubs, TV lessons on science, TV programmes of SITE for rural transformation, value conflicts arising out of science teaching, mixing up of science and arts teachers etc. i.e. almost everything exposed to research without any hesitation what so ever. That is necessary in order that science education in our schools imbibes the elements of humanism and scientism, and it does not remain ritualistic and mechanical as it is in most of our schools today despite the introduction of many so called innovative approaches in science education.

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11

Directions for the Future : Science Education Research in India

J. K. SOOD

A thorough study of the Science Curricular Projects, which were developed during the Post-Sputnick era, reveal that the most popular trends in science education were : Inquiry learning, Process Approach, Individualized Instruction, Environmental Studies, Problem Solving, and Integrated Science. These trends were aimed at to prepare scientifically literate citizenry with an understanding of the physical world, an understanding of the applicative use of science, as well as the relationship of science and technology Unfortunately these massive efforts did not prove very efficacious and the enrolment in science courses continued to fall. Therefore, very recently many new dimensions have been added to science teaching These dimensions are 'values and science teaching', 'man and his enviroment', 'humanizing science teacthing' etc. The main purposes are to teach science heuristically so that the concepts can be discovered by the students through experimentation. In other words students must study the methodology of science to acquire attitudes and concepts. An attempt is to be made to present science as a human activity where each student could progress independently and with maximum personal growth.

These new tasks demand new approaches, new understanding, and a closer relation between theory, research and practice than ever existed before. Research must be an integrated part of developmental programmes to provide pedagogical merit and social relevance. Such a power of research have been demonstrated in medicine and agriculture. This is to be proved in science and mathematics education through research. The strength of such research efforts depend on the availability of expertize, funds and interest shown by scholars from other disciplines, that is sociology, psychology, anthropology and economics. Once the necessity of research is acknowledged by the profession, then it will not be difficult to groom the research workers as experts in various areas of science education.

Directions of Research

If we trace the history of science education research in India, we find some isolated studies attempted by individual researchers from time to time. Some research attempts have also been made by M. Ed. and Ph. D. scholars to fulfil the requirements of the degree. The beginning of an organized research in science and mathematics education was started by the National Council of Educational Research and Training and State Institutes of Science Education. It means science education research is of recent origin in India. Most of the researches were of 'developmental' and 'service' nature. It was related to the reform of education system, reorienting education to newly emerging goals, educational planning reorganization of curriculum, preparing science text books and teaching aids and improving the evaluation procedures. Almost in all the States Survey studies were undertaken to determine the status of the different areas of education. In science education most promising attempt was made in curriculum development, textbook writing and evaluation procedures. In the early beginning these programmes were based mainly on adaptation of new science materials developed in Western Countries. The programmes have now [illegible] the adaptive phase and become a professionally systematic exploration of new content, new methods and materials. It is possible to infer a reasonable conclusion from these attempts of two decades in post-independent India. The term 'science education research' was given a broad and liberal definition, to include development and service programmes as its major components. Basic research in science education was not attempted. Status studies proved helpful in bringing a suitable change to some extent. One of the most useful research attempt was for identifying and nurturing the potential talent in science. Studies concerning this area hopefully, proved a rich contribution to the field of science education research.

It is evident that many factors influence the direction of research. These factors are related to the needs of the educational system, availability of expertise and funds; and the desire to enrich the field. It means there is a need to understand science education research in its correct perspective, to determine the priorities to examine its social relevance and a zeal to unearth new areas. It is essential to create an innovative intellectual ferment in science education research to provide new direction. This monograph has described many significant areas of research in science education. Though nobody would deny research attempts in curriculum evaluation, Piagetian Thinking, Sociology of Science and Science Education after knowing the existing status of science education research in India. Yet there are many other new areas which need attention of the workers in the field. Some emerging and relevent needs are as follows which will provide directions for the future :

1. The nurturing of talent in science from different socio-economic strata.

2. The nurturing of talent in science from rural areas and deprived classes.

3. Problems related to the sociology of science and sociology of science education to avoid further disjunction between science and society.

4. Advantages in preparing the value oriented science curriculum projects in schools.

5. Preparing science teachers to develop teaching skills, teaching style and teaching strategies.

6. Development of science concepts in relation to the developmental growth of children.

7. Development of functional scientific literacy. Specific attention is to be given on the first generation school going children.

8. Evaluative studies to answer the question of accountability and relevance.

Future Perspectives

In India various educational agencies are engaged in science education research in several areas. These areas are: (1) different aspects of child development, (2) the organized ways of learning science, independently or in a integrated way, or in a coordination way. (3) the areas of teaching and teacher preparation, and (4) the evaluative procedures

In addition to these some researchers are engaged in other aspects, such as, philosophical studies of the nature of science, historical studies of science as a component of the total curriculum, and sociological studies of the learners, teachers and the community at large. These areas are to be explored carefully so that a theoretical research frame-work can be evolved. Some of the precautions at the starting point is essential. A line for action is presented

There should be co-ordination among different educational agencies. Some of the research projects sho [illegible] conducted at the national-level. One of the most s[illegible] example is that of International Association for the Evaluation of Educational Achievement. This organization has conducted many international studies. Science Education in Nineteen Countries : an Empirical Study (1973) by Comber and Keeves is a brilliant example of international co-operation in science education research. Similar studies will prove useful if conducted in different states. There is an urgent need for a properly organized, systematically coordinated continuing programmes of science education research. Co-ordination in conducting research is not sufficient in itself. There is a need of co-ordination in dissemination of research findings